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Raw Materials

Most buyers of raw materials for the foundry industry will remember the times when, month by month, the prices of pig-iron, coke and scrap were gradually, almost imperceptibly, attuned to the demands of the market. Nowadays all this is changed, and adjustments to prices are of such a drastic character that they warrant the calling of a meeting of the board of directors of each individual foundry, and co-operation through the employers' federations with other foundries to determine future policy. It is no question of merely passing on the mathematical percentage of the reduction to the customer, for the pig-iron producers have recognised that the foundry industry was paying too much for its raw material, presumably in relation to current selling prices of castings, and not as related to problematic future quotations. Then as foundries do not and cannot work efficiently without stocks, it must be realised that some time will pass before the beneficial effect of the lower level of prices is generally felt. Some foundries will retain in stock their existing supplies and commence immediately taking and using material at the new level, well knowing that should conditions necessitate their drawing on the present stocks, in all probability the then-existing price level will amply justify its consumption. Naturally, not all foundries can afford the luxury of stocking large quantities of iron bought at high cost.

It is significant that, unlike "basic" pig-iron, no period is stipulated before price revision may take place. To our mind, this is a very good reason for entering the market at the new level, for the existence of stocks in the foundries is an excellent buffer against drastic changes. Cheap raw materials are an essential to the prosperity of the foundry industry, especially those concerns entering the export market.

Scrap Evaluation

We find it necessary to clear up a misunderstanding that has arisen through the publication of an article written by a member of our staff giving a formula for correlating the cost of remelted back scrap and the metal at the spout. By so doing it was not intended to offer the method disclosed as part and parcel of a costing system, but merely to help those people who for certain purposes—usually comparative—desire to solve such problems. For actual costing purposes we support wholeheartedly the unified system devised by the Costing Sub-Committee of the Institute of British Foundrymen.

Actually the question arose not out of foundry costing, but in connection with the tabulation of the operating costs of various types of furnaces. Here an arithmetical balance had to be introduced and our formula can be easily and effectively applied. We are aware of the "snowball" effect so aptly dealt with by "Mathemagician" in recent correspondence, but the mentality disclosed by this correspondent is such that, if we had propounded a case for using hypothetical market prices, he would have referred to the German inflation period of 1922, when it cost an odd milliard of marks or so to send a letter to the Editor! Again, if we detailed a system based on the supposition that during the year a foundry made and sold 15,000 tons of one sort of casting and to do this it used £15,000 worth of scrap, making the cost of scrap £1 per ton of finished castings, "Mathemagician" would crave for such details as "melting losses" and the incidence of periodic variations due to changes in market prices.

No system is perfect, but the underlying principle of a "unified and nationally accepted system of costing" does make people cognisant of the whole of the factors operating, and so tends towards the abolition of unintentional price cutting. Common-sense compromises between such factors as intrinsic value and calculated cost, and the accountant's angle and the valuer's viewpoint, are evident in the best of published costing systems.

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Evaluation of Returned Scrap

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—Your issue of December 22 contains a column article on the "Evaluation of Returned Scrap." This at first sight is a simple problem, but it is one over which there has been a considerable amount of argument, as the Technical Sub-Committee on Costing of the Institute of British Foundrymen has found.

Your contributor represents one school of thought, but one which I submit does not find much favour in everyday works practice. The question is largely an academic one, since whether the returned scrap is costed at 10s. per ton or 100s. per ton, the final cost of the castings remains the same.

I submit, however, that the value of the returned scrap is not what it has cost to make, but its value in the open market. Your contributor appears to have confused cost and value. The figures he gives of 176s., 149s. and 126s., as the cost of producing that returned scrap, are of course quite correct, but it would be very foolish to use such figures for the subsequent metal in the ladle costs. The scrap should be debited back to the metal melting department at its commercial value, and any loss must be borne by the moulding department, that is, the castings themselves. The melting costs should be ascertained as if the whole of the charge were purchased outside, otherwise, by the process of snowballing, one is going to get almost astronomical figures for metal in the ladle costs eventually. For costing purposes for metal in the ladle the acid test to apply as regards the returned scrap is: What are you prepared to pay for scrap of this character and analysis in the open market? Whatever that figure may be, whether the metal is iron, steel or bronze, it should be used in the costing of the metal in the ladle. Returned scrap should be credited to the foundry department and debited against the metal melting department at that figure.—Yours, etc.,

F. W. ROWE
(Penistone Manager).
David Brown & Sons (Hudd.), Limited,
Penistone, nr. Sheffield.
December 29, 1938.

[It should be made perfectly clear that no costing system was advocated in our small article. Its object was the plain application of arithmetic to *one method of ascertaining the cost of returned scrap.* The receipt of a number of letters of thanks shows that the formula has been appreciated by a number of foundrymen, who previously had been adopting a trial and error method.—EDITOR.]

Pig-Iron Supplies

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—Some thirty years ago, when most foundries made their cupola charges by rule-of-thumb method without regard to composition, a number of foundrymen of the more progressive type persistently pressed pig-iron manufacturers for greater consistency of composition. One iron with so-called hereditary qualities was said to vary from 2¼ to 3½ per cent. silicon in the same truck. In the case of hematite pig-iron, iron-founders said they got only what the steelmakers would not accept.

A blast-furnace manager at that time said the founders got what they asked for, that to know the composition would be of little use to them, and that as soon as there was a demand pig-iron makers would meet that demand following the better education of the foundryman.

In 1938 the foundryman is still being told that "... this pig will carry more scrap"; that "... owing to the variation in composition of the cast from start to finish of each tap, large variations in silicon contents cannot be avoided"; that "... other foundries do not complain, and it does not matter to them what the silicon variation is so long as it exceeds — per cent." Such remarks are not complimentary to a foundryman's intelligence. Or maybe some of us are mistaken, and most foundrymen make their charges up as follows: Say 5 of pig and 5 of scrap, and if anything goes wrong add a bit of Scotch (pig-iron), or use a bit more coke, change the ganister, blame the weather, etc.!

We refuse to believe that a majority of foundries are still run on the above lines. It would be impossible to do so unless the type of casting they produced were comparable with sash weights. Even firebar castings would justify better methods.

Forty years ago the American founder could obtain machine-cast pig-iron, but one of the troubles appeared to be that because of the closer grain obtained in the pigs it was considered inferior from the "scrap carrying" point of view. The producer, for his part, was also unable to sell as much sand with his pig-iron as previously. It is only in comparatively recent years that machine-cast pig-iron has been made in this country, but there is no doubt as to the advantage derived from it. It renders possible the production of a fairly uniform pig-iron in quantities equal to at least the weight of a tap or cast, due to its being collected in and poured from a mixing ladle. A further advantage due to machine-cast pig-iron is the reduced wastage of heat and flux, as there is less material to raise to a temperature sufficient to make it flow as slag, with the resultant loss of that heat, apart from the effect on the cleanliness of the cupola.

We are often told that the by-products obtained from the blast furnace are of sufficient value to make the pig-iron production of minor importance. This is not consistent with the mainly artificial inflation of the price of pig-iron, and it is high time that pig-iron production was modernised at least to the extent of supplying it machine-cast.—Yours, etc.,

F. ANDREW
(Foundry Manager, Ferranti, Limited).

Imported Ferro-Silicon

On the recommendation of the Import Duties Advisory Committee, the Treasury have made the Import Duties (Exemptions) (No. 7) Order, 1938, which provides for the addition to the Free List from December 23 of alloys containing less than 95 per cent., but not less than 90 per cent. of silicon. Silicon and alloys thereof containing not less than 95 per cent. of silicon are already exempt from duty under the Import Duties (Exemptions) (No. 14) Order, 1934. The inclusion of alloys of silicon was intended to cover the material with a high silicon content which was not eligible for free admission as ferro-silicon, but experience has shown that from time to time there are importations of such alloys containing between 90 and 95 per cent. of silicon which cannot be regarded as ferro-silicon. Similar material is not produced in this country, and the Committee consider that the scope of the exemption should be extended to include these importations.

Questions and Answers about Coal

A useful little booklet entitled "100 Questions and Answers about Coal" has been issued under the auspices of the Mining Association. Within the compass of these hundred questions an attempt is made to deal with all the important subjects that crop up in public controversy or private discussion about the coal industry. Those who feel the need of some such publication containing a condensed summary of information contained in numerous books and reports, will find this little volume particularly useful. Copies may be obtained from Philip Gee, Limited, 5, New Court, Lincoln's Inn, London, W.C.2. (Price 3d. post free.)

Random Shots

The year is still very young, yet everyone already will have had plenty of time in which both to make and to break good resolutions. So instead of adding more to a doubtful list, here are a few thoughts for the New Year, to ponder over, perhaps, whilst sipping that excellent Armagnac and puffing at that rich Corona Corona, both of them concrete expressions of goodwill from friends at Christmas time.

* * *

Firstly, one can hardly help thinking that, although a year older than at last New Year, there are mercifully some things, like the Armagnac, which grow better with age. One might even say richer, but let the conception of richness be confined to mellowness and warmth of feeling rather than to money. And the thought is a happy one for all with greying hairs and flagging energy.

* * *

When everyone so heartily wishes his neighbour "A Happy New Year," he is probably only doing his best to forget how much there is to be paid out in that hard month of January. For, as Mrs. Muggins (a veritable Mrs. Malaprop) says: "It sure takes the gilt out of a pound, when that's all you've got and the insurance man bangs on the back door for 13s. 4d. of it." But Mrs. Muggins usually manages to let in the New Year with a warm drop of gin and a light heart, whilst Master is bravely trying not to feel the burden of that income tax demand which lies heavy in his breast pocket.

* * *

Decoration on the theatrical stage is becoming so noticeably influenced by the present "steel age," and foundries are becoming so gay as new standards of lighting and comfort are enforced, that soon it will be difficult to tell one from another.

* * *

It is a strange thought that a picture by Millet, for instance, is worth a thousand times more than the value of the field, produce, cart and other implements that it represents; a few strokes of the brush, as it were, as against years of cultivation and labour!

* * *

Mr. Mills, of circus fame, is reported to have said at his inaugural luncheon, given recently in London, that the circus is the one league of nations that really works. Foundrymen who take an interest in the international events of their Institute have liked to think that their International Technical Committee has for many years proved itself to be a league of nations that really works. The members of the Lancastria Club have also claimed this for themselves, so Mr. Mills cannot have it all his own way, although for a spectacular manifestation of a league of nations he naturally carries the day.

* * *

A good story from Manchester concerns a West African trader who was behind with his payments. He placed a large order with a Lancashire firm, only to be told that they could not supply it until his outstanding account was settled.

His reply came as follows: "Cancel order. Unable to wait so long."

* * *

A little girl was heard to remark after the Christmas Day festivities were over: "Well, I know I've had a jolly day because my hands are dirty."

This, in conclusion, might be a happy formula for the foundry worker throughout the coming year!

"MARKSMAN."

Wear Resistance of Cast Iron and Malleable Iron*

By W. WEST and C. C. HODGSON

This survey of ferrous materials for wear resistance covers experience that has been obtained, mainly, in connection with the internal-combustion engine. Two factors have been kept in mind:—(1) The direct value of any development of such material to the resistance to wear; (2) the suitability of the materials, and the methods, for use in commercial production processes.

It will be seen that certain sections of the Paper contain information which, while not directly connected with the main issue, has some bearing upon the practical difficulties in manufacture, and show what steps have been necessary to balance the disadvantages against the advantages in the use of particular classes of material. In setting out the results of experience and experiment, it is with the hope that any underlying principles, which may emerge from the results, will be applicable to other branches of engineering.

Present Development of Cast Iron

A comparison of the requirements of the two British Standard Specifications, No. 321 issued in 1928, and No. 786 issued in 1938, based as they are on the results of tests regularly produced in commercial practice, gives a clear indication of the improvement in high-duty cast iron brought about by ten years of development. It will be seen from the last column of Table I that, in instances where comparisons can be made, the new specifications mean an approximate increase in the minimum ultimate tensile strength of 80 per cent., based on the 1928 requirements.

How far the increase of tensile strength is of value to the engineer is difficult to determine because of the many and various uses for which cast iron is available. It may be that, by the use of stronger cast iron, scantlings may be reduced, and in many cases resistance to wear be increased. Suffice for the moment to state that such increases in tensile values are at least a commercial success, and may be achieved in one of two ways:—(1) By the control of the structure in general; (2) by the control of the amount of graphitic carbon present, and the size and shape of the flakes in which it occurs.

Strict metallurgical control of composition in the production of modern cast iron, and the conditions under which it passes from the liquid to the solid state, is of great importance. During the last ten years, a much better understanding of the influence of the amount, the size and shape of the graphitic carbon, and its relative influence and importance to the remaining elements which go to make up the composition of cast iron, has definitely put into the hands of the producers the means of obtaining high-strength irons, and the functional suitability to most preconceived conditions of service. For example of this, the diagram, Fig. 1, gives substantially the whole range of combinations of total carbon and silicon to yield grey or white iron, the limits under theoretical conditions of each, and also the positions at which malleable cast iron and steel can be produced.

The shaded portion encloses a field of combinations between the two elements, in the range of cast irons, which has not as yet been commercially developed. Below 2.5 per cent. total carbon, the physical behaviour of cast iron in the liquid state becomes very difficult to control for the production of sound castings. It is particularly in this range, *i.e.*, 2.5 to 1.7 per cent. total carbon, that much of the present development work is being exercised. One practical example of the strength possibilities in this range was obtained from the following composition:—T.C, 1.74; Si, 0.62; Mn, 0.63; S, 0.05; Mo, 0.64; and Ni, 1.94 per cent. This material, as cast, showed a fine-grained white fracture, which, after an annealing and heat-treatment as follows:—

9 hrs. at 1,000 deg. C., cooled to 950 deg. C.
8 hrs. at 950 deg. C., cooled to 900 deg. C.
7 hrs. at 900 deg. C., cooled in air.
Reheated to 900 deg. C., transferred to a furnace at 650 deg. C., held for 1 hr., then cooled in air.
Re-heat-treated to 850 deg. C., for 1 hr. and cooled in air, tempered at 550 deg. C.,

produced an exceptionally fine-grained material giving a tensile strength of 63.2 tons per sq. in. This, as far as can be ascertained, is the highest

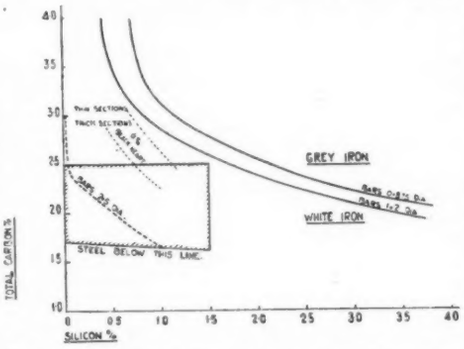

FIG. 1.—SHOWING TRANSITION FROM WHITE TO GREY IRON FOR BARS OF VARIOUS DIAMETERS AND COMPOSITIONS.

The mottled region between white and grey is a *region* and not a line; hence the curves are only approximate. The fracture is also affected by the nature of the mould and by inoculation effects, especially in heavy bars. The heavy broken line is the transition line (very approximate) for 2.5-in. bars.

tensile-strength figure obtained from cast materials of this kind. The greatest difficulty arising in the commercial utility of such material is the intensive shrinkage which occurs when passing from the liquid to the solid state.

To appreciate the full possibilities, however, of the developments which have been made in cast iron, it is imperative to consider the physical structures of such material, and not to limit them in terms of mechanical properties.

By way of comparison in the common grey iron, say, covered by Specification No. 321 of 1928, Grade C, the tensile strength seldom exceeded 9 tons per sq. in., and three reasons for this figure are well known.

First, the high percentage of phosphorus then general in the composition gives rise to the presence of a brittle, hard and weak constituent in the structure; secondly, the main portion of this structure is built up of a steel-like material intermixed with a proportion of very soft iron; and thirdly, graphite flakes truly characteristic of cast iron, being large in size, numerous and abundant in distribution.

The present-day development has been achieved chiefly by some modification of one or more of the three features found in the earlier type of grey cast iron. The most outstanding change is that of the amount, shape and distribution of the graphitic carbon as previously stated. Some ten years ago general engineering learned something of the possibilities in this direction when the German Lanz-Perlit process gave increased tensile strength of the order of 16 tons per sq. in. by producing in the structure an entirely pearlitic or steel characteristic of the matrix.

Later, the amount of total carbon was lowered, according to the class of work to be produced, from 3.5 per cent. to 2.7 per cent. Such irons have the great advantage that the graphite content is lower, which makes for greater strength, because the weak flakes of graphite are smaller and therefore these planes of weakness have less effect upon the strength of the remaining matrix. Cast iron of low total-carbon content is invariably accompanied by a pearlitic structure, which gives improved resistance to wear, and combines this characteristic with a high mechanical strength. Both properties are very desirable for highly-stressed or wear-resisting parts of machinery.

Inoculated Irons

Organised attention has been given of late to the inclusions which occur in cast iron, and certain schools of thought have put forward the theory that it is possible, by the distribution of a large number of nuclei within the bulk of the molten metal, to produce a corresponding large number of graphite flakes which will be of much smaller dimensions than usual. By adding a graphitiser, *i.e.*, some addition which will cause the graphitic carbon in the molten metal to be thrown out, the graphite commences its formation around the inclusion particles. The graphitiser may be calcium silicide, ferro-silicon, aluminium, or a mixture of nickel and ferro-silicon. The first to be used was calcium silicide, and the resultant iron is sold under British patent No. 210,118, and the name "Meehanite." A high grade of iron can be obtained, giving a rising tensile strength to 23 tons per sq. in. for unalloyed iron.

In the case of the patent held by the Mond Nickel Company, Limited (British patent No. 290,267 of 1927), the graphitiser is a mixture of nickel and ferro-silicon, and the addition is made as usual to the molten metal as it runs from the spout of the cupola. This cast iron is sold under the trade name of "Ni-Tensyl."

TABLE I.—*British Standard Specifications, Showing Tensile Strengths in Tons per Square Inch.*

Test-piece.	Original—1928. Specification 321.		1938. Specification 786—1938.			Increase of Grade 3 over Grade A. Per cent.
In.	Grade C.	Grade A.	Grade 1.	Grade 2.	Grade 3.	
0.875	10	12	15	18	22	83
1.2	9	11	14	17	20	82
1.6	—	—	13	16	19	—
2.1	9	10	12.5	15	18	80

The outstanding feature in the production of the so-called "inoculated iron" is the necessity for a low silicon content in the original molten iron. Table II shows the beneficial effect in this direction. From the base iron with the lowest silicon content comes the resultant iron with the highest maximum stress.

Inoculated irons are characterised by a very close fracture without the danger of hardness during machining. This type of iron gives, in contrast to the low total-carbon cast irons, a

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* Extract from a Paper read before the Institution of Locomotive Engineers in London.

higher tensile strength; but as far as the general view is accepted, no greater resistance to wear is obtained.

Super-Cooled Graphite Iron

This material embraces the latest and most extended methods of graphitic carbon refinement in cast iron. It is readily appreciated that the form in which this graphite occurs has a very great influence upon the strength, structure, and mechanical behaviour of the iron in service, so that this particular process of refinement is more applicable to the higher carbon irons usually termed common irons, than to such irons previously referred to.

To the molten iron is added a pre-determined quantity of ferro-silicon-titanium. It is thought that the titanium exerts its influence by covering the slag particles with a liquid layer of titanium-bearing slag. This effect creates a condition where the molten slag particles cease to act as nuclei, with the result that the carbon remains in solution for a longer period, and is precipitated at a lower temperature than usual, in a very finely divided state. Cast iron produced in this way gives a very close fracture and is free from porosity. Accompanying the formation of super-cooled graphite is, invariably, a large proportion of ferrite, or free iron. As to the extent to which this particular iron has been tested in commercial practice, results indicate that it is not outstandingly resistant to wear under lubricated conditions, and under dry wear it is specially unfavourable, as the softer portions are picked out and carried on to the accompanying material.

TABLE II.—*Inoculated Irons made from Variable Silicon Content in the Base Iron.*

Silicon in base iron. Per cent.	Final analyses. Per cent.						Mechanical tests.	
	T.C	Si	Mn	S	P	Ni	Size of test-bar. In.	Tons per sq. in.
0.57	2.95	1.90	0.66	0.03	0.045	1.41	0.875	23.4
0.92	2.89	2.07	0.83	0.025	0.025	1.52	0.875	22.4
1.04	2.88	2.00	0.82	0.025	0.070	1.60	0.875	21.33
1.35	2.98	2.00	0.73	0.026	0.040	1.52	0.875	19.00
1.66	2.98	2.00	0.69	0.020	0.040	1.53	0.875	18.68

Phosphorus Content and Porosity

By virtue of the methods of manufacture, the various kinds of cast iron enumerated lend themselves to a low phophorus content. This feature is of great assistance to founders, who have as a primary object the production of sound castings. The following experiments were carried out as part of a larger scheme to determine precisely the influence which phosphorus exerts upon the production of sound castings. For the purposes of the experiments, test specimens of a shape having various thicknesses were taken, which would approximate as nearly as possible to such designs as are met in general design. One section, therefore, was devoted to the production of cylinder heads for petrol engines, the design of which embraced the usual junctures of sections, also small passages to form the necessary waterways for cooling purposes. It is helpful to note that it was because of trouble through leakage on water-pressure test that this particular case stood out as an excellent basis for experimenting in this direction. The composition of the cast iron used was standardised in every detail of its make-up, except for a predetermined increment in the amount of phosphorus present. For example, the general composition ran as follows:—T.C, 3.60; Si, 2.00; Mn, 1.90; S, 0.045, and P ranging from 0.29 through 0.42; 0.52; 0.61 to 0.98 per cent.

The castings were in every case poured at the same temperature of 1,350 deg. C., exactly in the same manner, so that the conditions were correct for a true comparison of the results obtained. These were of a conclusive character. There is found an increasing evidence of porosity in the centre part of the casting with the increasing percentage of phosphorus. It will be evident that the best results are obtained with the phosphorus content under 0.3 per cent. This has been borne out in practice, and it is now generally recognised that for intricate castings it is much better to run a composition containing phosphorus not above 0.3 per cent., if soundness in the sections is the important feature required.

Similar experiments were carried out in the manufacture of cylinder castings, and the results were confirmed that, where the phosphorus content was controlled to under 0.3 per cent., sections which come together between the cylinder barrels are obtained with satisfactory soundness. The exception to this result occurs when the total carbon falls below 3.0 per cent.; a higher phosphorus content then has not the same effect, but external sinking at junctures of sections and heavy bosses takes place.

From the machine-shop point of view, the importance of the phosphorus content in relation to sound castings is evident, because not only can the production line be kept without serious interruption, but the rate of machining can be accelerated. In relation to the subject of this Paper, however, such factors are secondary to the great disadvantage there is in using low phosphorus irons, their resistance to wear in comparison to the higher phosphorus cast irons being considerably less. Considering this point of view, and the mass results obtained from road service, the company to which both authors are attached changed their policy and adopted a system of dry liners, which are inserted in the cylinder barrels. This decision has enabled the company to produce the softest type of cylinder casing, consistent with the strength required, and yet to have the conditions of the material inside the cylinder barrels most suitable for the maximum resistance to wear. It became necessary, therefore, to determine what composition would effect the best results, knowing that in any composition a much higher phosphorus content would have to be used than that employed in the making of the block itself. To this end, an extensive set of experiments was formulated and carried out, and the results of these are set out in the next section.

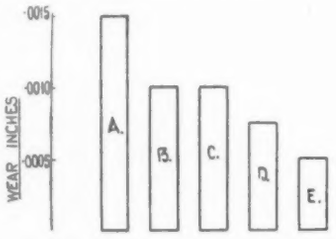


FIG. 2.—DIAGRAM SHOWING THE AVERAGE OF LINERS MADE FROM IRONS GIVEN IN TABLE III (MEASURED) AT POSITIONS OF MAXIMUM WEAR.

Effect of Phosphorus on Resistance to Wear under Lubricated Conditions

While outstandingly benefiting from a low phosphorus content by the solidity in heavier sections of iron castings, the mass results returned from road service clearly indicated that, under petrol-engine conditions, the rate of wear was decidedly higher as the phosphorus content was reduced. It was, therefore, decided to put through experiments under controlled conditions of engine operation, to obtain accurate information regarding the rate of wear of certain selected cylinder materials.

(1) *Materials Selected.*—As the policy of the company to which both authors are attached is to use centrifugally cast liners in all engines, the various types of cast iron were prepared in this form, and all the results apply to this condition of casting. This point is important, because the structure of cast iron takes a somewhat different form when cast centrifugally, particularly in the formation of the separated graphitic carbon. There are also other structural differences, for example, more or less pure iron termed ferrite separates in the interstices between the fine graphite flakes in centrifugally cast iron. General experience confirms that, under similar conditions, irons with fine graphite formation, particularly in combination with separated ferrite, are less resistant to wear than those with an entirely pearlitic or steely structure and coarser type of graphite flakes.

Five selected materials were chosen for the engine tests, one in particular being tried in five heat-treated conditions, to ascertain whether heat-treatment with its accompanying alteration to the structure of the material had any relation or bearing upon the resistance to wear.

The tests were made in a six-cylinder petrol engine having a bore diameter of 3½ in. and a stroke of 6 in., run at full load with the engine set to deliver 70 h.p., at a speed of 2,000 r.p.m. The cooling water temperature was kept as low as possible with the object of increasing the rate of wear, the average temperature being between 55 and 60 deg. C. Particulars of the materials used will be found in Table III. All these dry liners were cast by the centrifugal process. The rates of wear are shown graphically in Fig. 2.

Material A was a 5 per cent. nickel cast iron, which was tested in various conditions of hardness. The rates of wear did not vary greatly in spite of the considerable difference in hardness number, and only one example has, therefore, been illustrated. The nickel present in these liners causes the material to be capable of air-hardening, and all the liners tested were in the air-hardened and tempered condition.

Material B is rather unusual in that it is cast in the white condition, and annealed to make it suitable for use and machining. As would be expected from the analysis, it contains a large

TABLE III.—*Analyses, Hardness and Heat-Treatment of Average Specimens of Liners.*

Liner material. Mark.	Chemical analysis. Per cent.							Diamond pyramid hardness No.	Treatment.
	C	Si	Mn	P	Ni	Cr	Al		
A.	3.4	2.1	1.0	0.7	5.5	—	—	340	Air-hardened after casting, tempered at 570 deg. C.
B.	2.8	2.7	0.45	0.06	—	1.5	0.5	285	As received from maker, special annealing treatment.
C.	3.6	2.3	1.1	0.7	—	0.2	—	240	None.
D.	3.4	2.4	1.0	0.8	—	0.4	—	288	None.
E.	3.4	2.3	0.9	0.8	—	0.7	—	340	None.

quantity of cementite embedded in a relatively soft matrix.

Materials C, D and E form a series of relatively soft irons. In the low chromium iron, the structure consists of mainly pearlitic matrix and hard iron phosphide, whilst as the percentage of chromium is increased, in addition to the hard iron phosphide present, there is present also primary cementite. It will be noticed that as the chromium is increased, the wear resistance increases.

Malleable Cast Iron

Having considered some of the problems associated with the wear resistance of cast iron, it seems to the authors natural that they should consider next malleable cast iron and related materials; products intermediate between cast iron and steel. There are two varieties of ordinary malleable cast iron, namely, white-heart and black-heart. Of these, one would consider only the former as a material suitable to resist wear. The latter, being composed essentially of graphite and almost pure iron (the metallographic constituent ferrite), has no value for the manufacture of parts required to resist wear, except for very unimportant applications.

Well-made white-heart iron, consisting essentially of graphite and laminated pearlite, is a material which gives good results when used for such parts as lightly loaded gears, and other parts where the stresses and pressures are not high. The presence of graphite aids machining, but it is important to ensure that sufficient material is machined from the surface to remove entirely the decarburised skin which is usually found on white-heart castings.

TABLE IV.—*Effect of Reheating and Normalising Black-Heart Malleable Cast Iron.*

(Test-pieces cast 0.564 in. dia. Machined after treatment to 0.424 in. dia. by 1.5 in. gauge length. Soaking time, 30 minutes.)

Condition.	Hardness No.	Ultimate tensile strength. Tons per sq. in.	Elongation per cent. on 1.5 in.	Izod impact. Ft.-lbs.
As received, normal black-heart fracture ..	109	23.0	17.0	11, 12
Heated to 800 deg. C., air-cooled	168	32.6	5.0	9, 8
Heated to 820 deg. C., air-cooled	178	36.7	5.0	7, 7
Heated to 840 deg. C., air-cooled	193	38.3	3.5	5, 6
Heated to 860 deg. C., air-cooled	207	44.2	2.5	5, 4

Although well-made white-heart machines fairly well and takes a good finish, the advantages offered by black-heart to the production engineer make it a very tempting material. It may be machined, for instance, at a speed of 120 ft. per min. using high-speed steel, or at 400 ft. per min. with carbide-tipped tools, compared with only one-half of these speeds for good white-heart malleable cast iron.

The authors understand that there is a fairly common belief that black-heart malleable cast iron cannot be heat-treated. **This is incorrect,** and it is rather surprising that more has not been attempted in this direction, for by a correct sequence of operations and suitable treatment, it is possible to combine the advantages of rapid machining obtained from normal black-heart with the good wear resistance of white-heart. In this way the advantages of both processes are obtained. The heat-treatment consists merely of heating the parts up to a suitable temperature, which is generally between 850 deg. C. and 900 deg. C., and, after soaking, allowing them to cool freely in air. This treatment causes some of the graphite to pass into solution, and the relatively quick cooling causes the carbon so dissolved to form pearlite. If the treated castings are broken for examination of fracture, this should appear steely and not black as it would have been before treatment. Engineers will probably want to know what difference is produced in the mechanical properties by such treatment, and the data in Table IV will be of interest.

The authors have made use of a large number of black-heart castings treated by the process outlined above, with satisfactory results for lightly-loaded gears such as timing gears and chain sprockets.

Still nearer to the steel range there is a group of alloys, the members of which are best regarded as high-silicon alloy cast steels containing graphite, or as alloy malleable cast irons, although they are sometimes referred to as cast irons. Usually such an alloy in the condition in which it is used consists essentially of pearlite or sorbite with free carbide and graphite, the proportions of the two last constituents depending on the exact composition and heat-treatment. Many of these materials possess excellent wear-resisting surfaces. The success obtained by the Ford Company with their cast crankshafts, using a high-carbon alloy containing copper and chromium, is now well known.

The high strength and wear resistance of such materials naturally make them very attractive. It is unfortunate, therefore, that they are extremely difficult to handle in the foundry, as they have a very high solidification shrinkage, and, in the case of large castings, the number and volume of the heads required, together with the cost of removing them, may outweigh any economic advantage that might be expected from the use of a casting in place of a forging. The authors themselves during some experimental work with alloys of this type have produced one which they prefer to regard as a sort of heat-treated alloy malleable cast iron; some details of this alloy have been given in a previous section of this Paper. It will be remembered that it had an ultimate tensile strength of 63.2 tons per sq. in., with 1 per cent. elongation. So far, however, they have not been able to apply this alloy in practice for large castings because of the difficulties indicated above.

All the malleable cast irons and alloys considered in the last few paragraphs are characterised by the presence of graphite in the nodular form. The presence of the graphite no doubt has something to do with the satisfactory wear resistance obtained. Related to such materials are what have recently been referred to as graphitic steels. These are reported to have met with considerable success for the manufacture of dies, giving less wear and consequently longer life than the die steels previously used. These steels may be rolled and forged. In passing, it may be of interest to note that a graphitic steel was produced and sold by at least one Sheffield steel company about thirty years ago.

North-East Shipyard Output

Output from North-East shipyards for 1938 reached 91 vessels or approximately 401,000 gross tons, compared with 108 vessels of 360,000 tons in 1937. Swan, Hunter & Wigham Richardson, Limited, Wallsend and Walker, with an output of 98,191 tons, launched nearly two-thirds of the Tyne's total output and again built more tonnage than any other firm on the North-East Coast. The outputs for the three centres were:—Tyne, 25 vessels of 154,000 tons (compared with 24 vessels of 117,611 tons last year); Wear, 36 vessels of 150,000 tons (38 of 155,700 tons); and the Tees and West Hartlepool, 29 vessels of 99,776 tons (42 vessels, 85,523 tons). The biggest vessel launched was the "Dominion Monarch" (26,500 tons), built by Swan, Hunter & Wigham Richardson, Limited, Wallsend, for the Shaw Savill & Albion Line. The Tyne's output comprised 21 merchant vessels and four warships.

Chaplet Elimination

By H. R. THOMAS.

Chaplets are used to support cores during the assembly and casting of certain moulds of which the design is such that sufficient anchorage is not obtainable in the prints to enable the core to be secured against "lift" and other movement. There are many jobs where the use of chaplets is the cheapest and easiest way of securing the core, and is not at all detrimental to the finished casting. Other cases occur, however, when the presence of chaplets is not allowed because of the effects on the resultant casting; either they tend to cause miniature blowholes and so dislodge portions of sand in their vicinity which is revealed on machining as dirty patches; or they may not completely unite with the surrounding metal and thus cause "weeping" under the hydraulic test. If the design be such that it calls for this test, ways and means can be adopted to eliminate chaplets, but these methods are more costly in assembling time, and a higher price should be obtained for "chaplet-free castings." Two examples of chaplet elimination are shown in Fig. 1 *et seq.* Fig. 1 shows a portion of a cored-up mould which (because of other details) had to be jointed along the line A B. Core C, which was approximately 15 in. diameter, was supported in print D and also by chaplets or studs E. There were two of these in the bottom half of the mould and one on top. Invariably, on machining this cylinder, patches of dirty metal would be associated with the area surrounding the chaplets. Eventually it was decided to eliminate the chaplets and secure the core by other means. The method adopted is shown in Fig. 2, the joint still being along line A B. The core C is made on a grid F, in which two hooks are cast at G. These are opposite each other and about 2 in. below the line A B. The core is assembled on wooden thickness pieces and tested for centrality by a semi-circular gauge. Hooked bolts H are then fastened to the grid at G and bolted through the side of the box across gland J. The temporary wooden blocks are now removed and the top is ready for lowering. Castings produced by this method machine up quite cleanly, yielding a sound job.

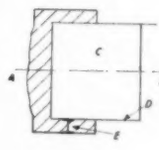


FIG. 1.

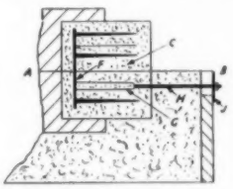


FIG. 2

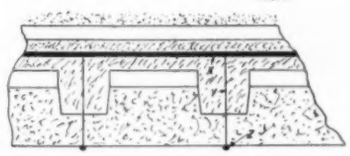


FIG. 3.

The second case is shown in Fig. 3, in which a core has a number of outlets at the bottom and none on top. For ordinary work perforated studs could be used to keep the core down, but in this case they were inadmissible as the castings were tested by water pressure. To overcome the problem provision was made in the core for its being secured in the prints by wiring, as is indicated, X being the support in the core, Y the wire, and Z the bar at the outside of the box to which the wire is secured.

W. H. A. ROBERTSON & COMPANY, LIMITED, of Bedford, makers of rolling mill plant, have secured an order for cold strip rolling mills for the Outokumpu Copper Company in Finland.

Some Notes on the Malleablisation of White Iron*

By MAURICE LEROYER

Two phenomena are exhibited when making malleable from white iron: (1) graphitisation, which is the outstanding factor in the manufacture of black-heart (American) malleable, and (2) decarburisation, which is the basis of the production of white-heart (European). In practice these two phenomena nearly always take place coincidently in the malleablisation of iron; what matters is that their action varies. In this Paper, it is proposed to set out the methods available to the metallurgist for utilising the

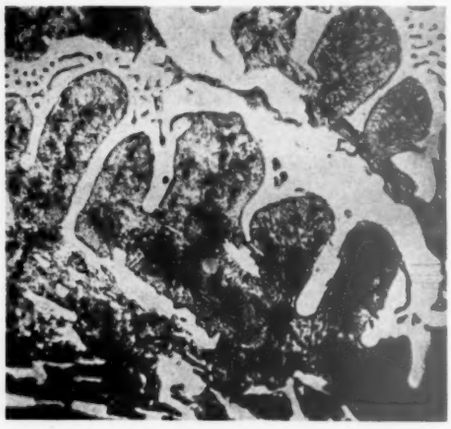


FIG. 1.—WHITE IRON. ETCHED NITRIC ACID. × 800.

relative importance of the rôle played by graphitisation or decarburisation during annealing, and from these factors modifying the structure and properties of the final product. It seems desirable to recapitulate briefly the factors which intensify the action of each phenomenon.

Graphitisation

When white iron consisting of cementite and pearlite at ordinary temperatures (Fig. 1) is heated up beyond the A_1 point, the latter constituent changes to austenite. With increasing temperature, the carbides, of which the solubility in austenite increases, commence to be dissolved therein, but before equilibrium of the austenite and cementite, as defined by the line E'S' of Fig. 2, can be reached, the less soluble carbon (line EJ of Fig. 2) is precipitated. The process continues until the complete disappearance of the carbides and the deposit in the free state of all carbon in excess of the quantity soluble at the temperature at which the metal is maintained. If the cooling subsequent to the complete dissolution of the carbides is sufficiently slow, the dissolved carbon separates out following first EJ, then JS. Fig. 3 shows the structure typical of the ferrite-graphite of the malleable so obtained.

By quenching the metal before the total disappearance of the carbides, then by rendering perceptible the carbon contents of the quenching constituents, it is possible to show up the slow change of the dissolved carbon of the carbides to nodules of carbon. Fig. 4 shows an iron so treated, wherein the gradual reduction in the carbon content goes on progressively as the graphite is approached.

A knowledge of the process of graphitisation makes it easy to understand that the speed of this graphitisation can be accelerated according to the magnitude of the difference in the solubility of the carbon and the cementite in gamma iron, or, what comes to the same thing, that the solubility curves EJ and E'S' are further removed from each other. This widening between the curves varies with the temperature. It also increases with the silicon content. On the other hand, everything is changed if there be an excess of sulphur, however small, over and above the quantity necessary for the formation of sulphide of manganese with the manganese present in the iron, and it would lessen the space between the curves EJ and E'S', and would bring about confusion at the transformation temperature A_1. Below the point Ar_1, the solid solution in equilibrium with the precipitated carbon changes almost integrally into pearlite. A slowing up of the drop in temperature only induces an enlargement of the size of the elements which constitute it. A very slight excess of sulphur therefore renders the cementite stable at the eutectoid temperature.

It can also be taken for granted that the decrease in passive resistance which opposes the migration of carbon in solution allows of the speeding up of graphitisation. The raising of the temperature also acts in this direction. According to Ishiwara, the speed of migration of the carbon in the iron is a logarithmic function of the temperature. The silicon, and generally speaking all of the elements which are soluble in iron, strongly increase passive resistance, but as has been shown elsewhere,[1] and contrary to current opinion, it does not seem that sulphur in excess has any marked action on the viscosity of the iron.

The carbides enter into solution all the more easily, and, consequently, the carbon-solid solution equilibrium is more quickly reached, as

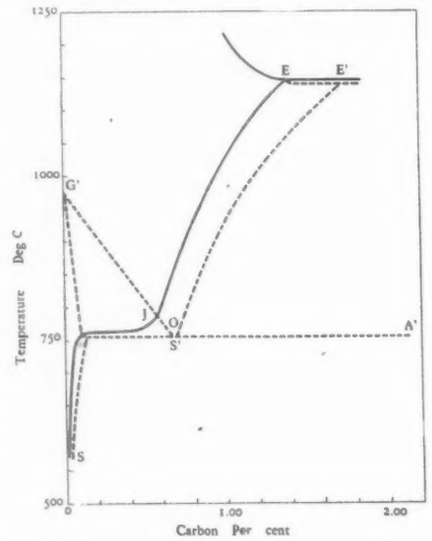


FIG. 2.—DIAGRAM OF TRANSFORMATION POINTS OF BLACK-HEART MALLEABLE CAST IRON CONTAINING ABOUT 1 PER CENT. SI.

their dimensions are smaller. In practice these dimensions vary in relation to the speed of cooling of the iron in the mould, and it explains why the graphitisation of the thick sections of a casting is always slower than the thinner ones.

Everything being equal, an increase in the number of nodules of carbon formed at the beginning of the annealing will bring about an acceleration of graphitisation by reducing the mean distance for the migration of the carbon and by rendering the variation of the carbon content of the solid solution which separates the carbides of the nodules during formation more rapid. This increase in the number of nodules perhaps comes about through an increase in the carbon content of the iron, so that, contrary to usual opinion, the duration of the graphitisation in no way increases with the quantity of carbides to be decomposed. The silicon itself also favours the formation on heating of the greatest number of nuclei for graphitisation. If present in too large proportions, it can even set up, especially when the carbon content is high, an auto-graphitisation of the carbides. The carbon then precipitates in a system corresponding to the ledeburite system in cast iron. The metal presents a dull grey fracture. Its breaking

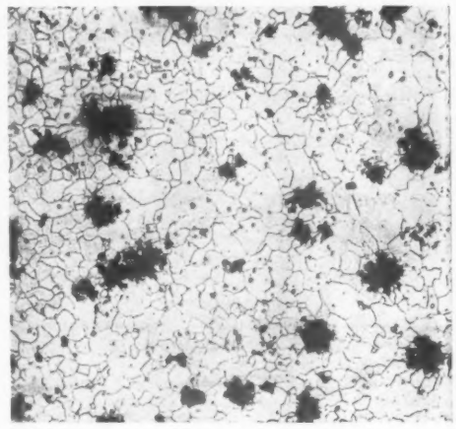


FIG. 3.—GRAPHITISED IRON. ETCHED NITRIC ACID. × 100.

strength is considerably lower, and such a material is useless.

The gases which surround the castings during annealing and dissolve in the metal favour graphitisation. These gases contain carbon monoxide and carbon dioxide in variable proportions. It will be shown later, when dealing with the decarburisation phenomenon that for certain concentrations of CO and CO_2, the following reactions take place:—

(1) $Fe_3C + CO_2 \rightleftharpoons 2CO + 3Fe$,
(2) $2CC \rightleftharpoons CO_2 + C$,

and finally may be:—

(3) $Fe_3C \rightleftharpoons 3Fe + C$.

The CO_2 and CO act as catalysers. Anson Hayes and Scott have shown that the action of CO and CO_2 can be intensified under the effect of pressure reaching up to five atmospheres. In practice, the use of slightly oxidising cements can be shown as tending to diminish the time of annealing necessary for malleablisation.

From the above, it can be deduced that the graphitisation can be speeded up by the following:—

(1) *By increasing the annealing temperature.*—This increase in temperature allows reactions to take place in the zone where the curves of the solubility of the carbon and the carbides are widest apart, but it decreases the viscosity of the metal and, if the annealing is carried out in the presence of an oxidising medium, it intensifies the catalytic action of the gases. All the same, too high a temperature tends to cause the graphite to precipitate into an irregular form, and consequently increases its strain and notch effect upon the ferritic matrix and sets up a marked lowering of the mechanical properties of the malleable castings so obtained.

(2) *By increasing the carbon content (increasing the number of nodules formed).*—Here again, considerations of final quality limit the

* Translated from "La Fonte."

[1] "La Malleable." Page 45. Published by Dunod.

possibilities. The graphite precipitated yields no real strength, and the space it takes up should be as small as possible.

(3) *By increasing the silicon content.*—Although it increases the passive resistance through its influence on the respective positions of the solubility curves of the carbon and the carbides in gamma iron, it clearly favours graphitisation. Its content should be maintained sufficiently low, however, to eliminate any risk of premature graphitisation of the iron during its cooling in the mould. The same remark applies equally to the carbon percentage.

(4) *By the complete neutralisation of the anti-graphitising influence of the sulphur through combining it with a suitable manganese content.*—A large excess of manganese should be avoided, although its anti-graphitising action is much less marked than that of sulphur.

(5) *By working in a slightly oxidising atmosphere in order to utilise the catalytic action of CO_2.*—An outcome of this action in practice is surface decarburisation, more or less pronounced in castings, which, though in general favourable, is detrimental in certain cases, and specially ought to be avoided in the case of ribbed or filletted shapes.

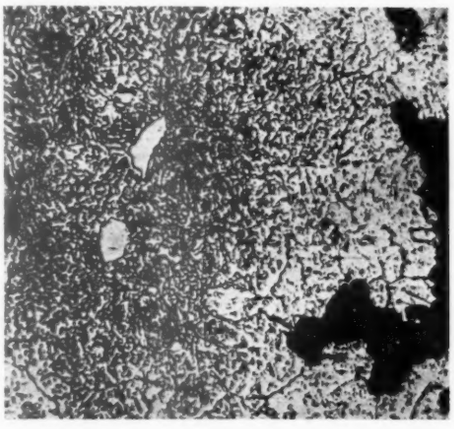


FIG. 4.—MIGRATION OF CARBON. ETCHED NITRIC ACID. × 1,000.

It should be remembered that the phosphorus, within the limits where it should be maintained in order to avoid all separation of the brittle phosphide during annealing, has no profound influence on graphitisation. On the other hand, in normal practice the metallurgist can modify the size of the carbides in the iron—these depending on the thickness of the castings.

Decarburisation

The decarburisation of the iron takes place through the combustion of the carbon by oxygen and carbon dioxide gases surrounding the castings. Fig. 5, due to Dr. Schenck, shows the diagram of the Fe-C-O equilibria in relation to the temperature, the summation of the pressures of the CO_2 and CO being supposed to be equal to atmospheric pressure. The presence of inert gases, especially nitrogen, in the gases which surround the castings during annealing, lowers the summation of the partial pressures of the CO_2 and CO and modifies the true values of the $CO : CO_2$ ratios, which correspond to the equilibria shown by the curves. It permits interchanging the respective positions of these curves.

The reactions shown on the diagram for each curve take place towards the right when the conditions of temperature and the composition of the gaseous mixture are given by a point situated above the given curve. Inversely, they take place towards the left when this assumed point is above the curve.

For the conditions of temperature and composition defined by the size of the diagram limited by the curves I and III, the iron, in the form of alpha or gamma according to temperature, is in equilibrium with the gaseous mixture. What takes place can, on the one hand, be shown by:—

(1) $Fe_3C + CO_2 \rightleftharpoons 2\,CO + 3Fe$,

and on the other hand by:—

(2) $FeO + CO \rightleftharpoons CO_2 + Fe$.

However, between the curves I and II, the carbon is not eliminated, but graphitised. The reversible reaction:—

(3) $2\,CO \rightleftharpoons C + CO_2$

takes place from left to right and the sum of the reactions (1) and (3) gives:—

(4) $Fe_3C \rightleftharpoons C + 3\,Fe$.

In the zone existing between curves II and III on the contrary, the carbon, which may be either free or combined, is eliminated.

The gases, rich in CO by the combustion of the carbon, are regenerated by the cement, generally iron ore, which cedes to them a part of its oxygen according to the equilibrium reaction:—

$$Fe_3O_4 + CO \rightleftharpoons 3FeO + CO_2.$$

The oxidising action of the gases on the iron takes place continuously from the surface to the core of the castings so long as the carbon content of the metal tends to equalise itself by the migration of the dissolved carbon of the portions rich in that element towards the impoverished surface layers. In the core, the cementite and then the carbon precipitated during the early stages of annealing, slowly dissolve in the solid solution.

After complete decarburisation, the cold metal consists of ferrite holding in solution, or in the state of combination (*combinaisons incluses*), the diverse elements originally present in the iron. Apart from castings of thin section, the decarburisation is practically never complete. After cooling down, the metal still contains in the core a small quantity of precipitated carbon disseminated throughout the pearlitic matrix, and a photomicrograph of this is shown in Fig. 6.

It is easy to deduce from the above the essential conditions for decarburisation. First of all, it appears from the Fe-C-O equilibrium diagram that the regeneration of gases is activated as the temperature increases. At the same time, the decarburising action becomes more intense for any given composition. The use of a "stronger" cement, that is to say, one capable

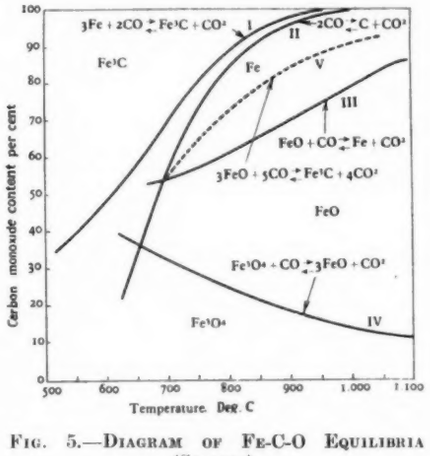


FIG. 5.—DIAGRAM OF FE-C-O EQUILIBRIA (SCHENK).

of easily giving up its oxygen, equally promotes decarburisation. Yet both those methods increase the risk of the surface oxidation of the castings, which only an increase in the speed of migration of the carbon towards the decarburised zones can, to a limited extent, take care of. This increase in speed must therefore be of cardinal importance, and it can be induced by a lowering of the silicon, and, generally speaking, of all the elements which, entering into solution with the gamma iron, increase the viscosity. Lowering the silicon, primarily, has the advantage of making the carbides more soluble, and consequently increases the difference in dissolved carbon content between the core of the castings and the surface, and thus accelerating the migration of the carbon towards the latter.

The getting into solution of the precipitated carbon and its oxidation by the CO_2 being more difficult than that of the cementite, it is necessary, in order to facilitate decarburisation, to reduce any tendency of the iron to graphitise to a minimum. Moreover, an easily graphitisable iron cannot give by decarburisation a high-grade product. Cavities corresponding to the carbon nodules remain, at least partially, after their elimination; they create discontinuities in the metallic matrix and tend to set up deep-seated oxidation of the metal. It has already been shown that a lowering of the silicon content, and the presence of an excess—no matter

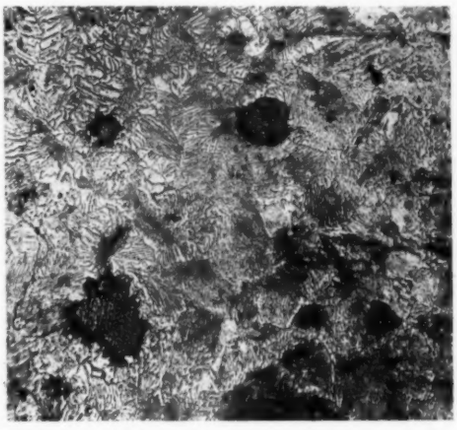


FIG. 6.—WHITEHEART MALLEABLE. CORE. ETCHED NITRIC ACID. × 100.

how small—of sulphur favour the maintenance of metastable equilibrium.

The lowering of the average volume of carbides—a function of the speed of cooling of the iron in the mould—helps towards solution and consequently promotes decarburisation. Thus it is evident that the decarburisation of thin castings will be quicker than thick ones.

In short, decarburisation can be promoted by lowering the silicon; the presence of an excess of sulphur; elevating the annealing temperature and increasing the "strength" of the packing medium.

It has already been shown that, beyond certain limits, the increase of the last two factors brings about the oxidation of the iron. Besides, practical considerations (deformation of the castings; oxidation of the annealing pots) do not permit of the use of excessive temperatures.

Lowering the silicon is practically limited by the risks of separation of the system, during cooling, of the pro-eutectoid cementite, within the incompletely decarburised zones. The malleable iron then presents all the characteristics of steels, usually and incorrectly called "abnormal." Its brittleness becomes excessive.

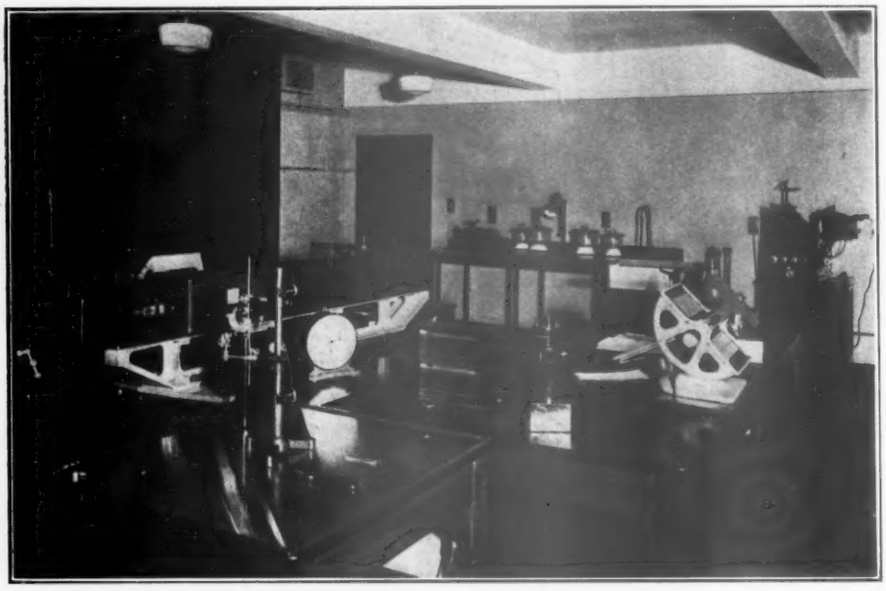
By itself, the quantity of excess sulphur can reach relatively high proportions without detriment. If a comparison is made of the influence of various elements in the iron and the factors associated with annealing in the two processes, it will be seen that such matters as temperature and the strength of the packing material have an action more or less similar so long as other factors act in the opposite direction to them. Silicon in particular as the best of graphitising media slows up decarburisation. Sulphur, on the other hand—an anti-graphitising agent—permits of the increase of annealing temperature without

(*Concluded on page* 8.)

The New Admiralty Laboratory at Sheffield

A new Admiralty Laboratory was opened at Sheffield on December 15 by Sir William Bragg, O.M., K.B.E., B.Sc. (President of the Royal Society), in the presence of the Lord Mayor of Sheffield and the Master Cutler. The building, which occupies a site of 5,400 sq. ft., adjoins the Admiralty Gauge Factory in Bold Street, and consists of a two-storeyed steel and red-brick structure, with an intermediate floor on one side, and a basement. The lay-out is on essentially utilitarian lines, and incorporates the latest developments both in construction and equipment. The whole building is served by an air-conditioning system, which provides eight changes of air per hour in the chemical laboratories, and four changes in all other rooms.

The basement contains the air-conditioning plant, boiler room, and store for liquid chemicals. A 1-cwt. lift connects the latter with the chemical laboratories and with the store for solid chemicals, and apparatus which is situated on the intermediate floor.



PART OF THE SPECTROGRAPHIC AND METALLOGRAPHIC ROOM OF THE NEW ADMIRALTY LABORATORY AT SHEFFIELD.

On the ground floor a corridor runs the length of the building and separates a block of offices from a laboratory with an adjoining balance room, which are equipped primarily for the chemical analysis of iron and steel. Lining one side of the corridor are 50 pressed-steel hat and coat lockers.

Steel Laboratory

The dimensions of this laboratory are 45 ft. by 33 ft. by 18 ft. high. Windows which face south-east run the length of the room and extend from bench level to a height of 8 ft. The panes in the lower half consist of Thermolux glass, which provides insulation from the heat and glare of the sun. On the opposite side of the laboratory are seven fume cupboards. The walls and the fume cupboards are built of egg-shell mottled glazed fireclay blocks. The benches have teak tops and are fitted with cupboards, drawers, white glazed sinks, taps for gas, water and vacuum supply, and plugs for electrically-heated hot-plates, muffle furnaces, and other apparatus. The flooring material is red acid-resisting asphalt, which is rounded off at the junction with walls, benches and other fixtures to simplify cleaning. General artificial illumination is provided by eight 200-watt lamps with Benjamin Glassteel diffusers suspended from the ceiling. There are also bench lights and special daylight lamps for colour comparisons. The fume cupboards are lit from outside by tubular lights having anodised aluminium reflectors.

The balance room adjoining the laboratory contains, in addition to the usual balance-room equipment, apparatus for the determination of carbon in steel.

Non-Ferrous Laboratory

On the first floor is situated a large laboratory with an adjoining balance room, which are equipped primarily for the chemical analysis of non-ferrous metals and alloys. The dimensions of the laboratory are 60 ft. by 33 ft. by 18 ft. high, and its construction and lay-out are similar generally to those of the steel laboratory. It contains, however, several pieces of apparatus specially constructed to suit the work of the laboratory.

The adjoining balance room, which is very commodious, contains a modern micro-balance, 12 analytical and other balances, and an apparatus for analysis by electrodeposition. The latter consists of 16 stands, each fitted with a friction-driven rotating electrode holder. A single motor-driven shaft supplies the motive power. D.c. current is supplied to the apparatus by two Westinghouse metal rectifiers.

Metallographic and Spectrographic Laboratory

This comprises a room for the preparation of specimens for examination, one for the micro-examination of specimens and the evaluation of spectrograms, and a dark room, all situated on the intermediate floor, also a further room on the first floor which is used for the preparation of spark spectrograms, a rather noisy operation which it has been found desirable to separate from other work.

The equipment for metallographic work consists of the usual apparatus for the preparation of specimens, a hydraulic press for mounting specimens in bakelite, Vickers' projection, Watson, and other microscopes, Phillip's Metallix X-ray apparatus, and electrically-heated drying and mounting presses.

The equipment of the spectrographic section consists of three Hilger fully-automatic, large quartz spectrographs with both arc and spark attachments, 3 photo-electric microphotometers, 3 Judd Lewis comparators, a rotating logarithmic W-edge sector, and other accessories. This section has been responsible for a considerable amount of original research work, particularly on spectrographic methods for the quantitative analysis of steel alloys. Non-ferrous metals and steel are now being analysed as a routine, over 40,000 quantitative determinations having been made during the last 12 months. Further development work is in progress.

Heat-Treatment Laboratory

This laboratory is equipped with a "Birlec" furnace, and a Wild-Barfield high-temperature atmosphere-controlled furnace, both complete with panels for automatic temperature control, a temperature recorder, and time switch. There are also smaller electric heat-treatment furnaces, and a gas-fired furnace for melting non-ferrous metals. A high-frequency furnace is shortly to be installed.

The combined staff of the laboratory exclusive of clerks and laboratory attendants is at present 43, but if necessary it could be increased to 60 without inconvenience. Provision has also been made to permit of another storey being added to the building should circumstances demand it, without any dislocation of work.

Some Notes on the Malleablisation of White Iron

(*Concluded from page 7.*)

causing carbon deposition, and thus indirectly favours decarburisation

To get castings showing the optimum mechanical strength characteristics for a certain purpose, depends upon the skill of the metallurgist to co-ordinate judiciously all the factors reviewed above within the limits imposed by the melting and annealing plant placed at his disposal. Should he desire, for example, to utilise the advantage given when casting with a slightly increased carbon content in the iron without lowering the mechanical properties of the black-heart castings, he can intensify, within limits, the decarburising process. Should he wish to avoid the danger of incomplete dissolution of the solidification carbides in the core of thick-sectioned castings in white-heart, he will maintain in his iron a silicon content sufficient for setting up graphitisation in the core during the soaking period. The carbon so dissolved at the end of this period thus gives on cooling a high-strength pearlitic matrix, easily machinable and of good resilience.

It is thus possible for the metallurgist to modify the structure of his final product, and in consequence its mechanical properties, either by thermal treatment subsequent to normal annealing or accelerating the speed of cooling after the elimination of the carbides. The whole range of malleable responding to the various demands is thus made available. The field of application should continue to expand so as to include uses for which malleable was not envisaged even a few years ago.

Shotts Iron Company, Limited

Presiding at the annual meeting of the Shotts Iron Company, Limited, SIR ADAM NIMMO (chairman) said that while the profits for the year were approximately £20,000 less than for the previous year, the position of the company as a whole had been well maintained. During part of the year all the furnaces were in blast, but for some time production had had to be materially restricted, and stocks of pig-iron had been greatly increased. During the year the board had pursued a progressive policy in regard to capital expenditure, the outlay in this respect having been £45,000.

Institute of British Foundrymen

SCOTTISH BRANCH ANNUAL DINNER

The annual dinner of the Scottish Branch of the Institute of British Foundrymen was held in the Grosvenor Restaurant, Glasgow, on December 10. Mr. R. Ballantine, the Branch-President, was accompanied at the high table by the Right Honourable the Lord Provost of Glasgow (Mr. P. J. Dollan); Sir Wm. M. Marshall (Chairman of the National Health Committee, Motherwell); Mr. T. Makemson (General Secretary of the Institute); Mr. A. C. Gardner (President of the Institute of Engineers and Shipbuilders in Scotland); Mr. John Roxburgh (Past-President of the Sheffield Branch of the Institute); Mr. H. Winterton (Past-President of the Institute); Mr. R. Shaw (Chairman of Falkirk Section); and Mr. A. L. Mortimer (Vice-President of the Scottish Branch).

The loyal toasts having been honoured,

MR. T. MAKEMSON proposed the toast of the City and Corporation of Glasgow. He made reference to his first visit to Glasgow, and how he experienced the desire of the people to be friendly and helpful to the visitor, and his subsequent visits to the city had confirmed this early experience. It had often been debated whether the people made the character of the city or *vice versa*. In the same way it might be argued whether Glasgow made the Clyde or the Clyde made Glasgow.

A Great City

Glasgow was one of the greatest industrial centres of the world, and in shipbuilding was supreme. In that industry they had a good start, because the first steamship was built on the Clyde, and he believed also the first turbine-driven ship, and finally there had been recently launched the greatest ship of the age—the "Queen Elizabeth." The foundry industry was intimately bound up with shipbuilding, and the work turned out on Clydeside compared favourably with castings made anywhere in the world. Every great city realised that it must have ample activities to provide employment for the population, and must let the people live in reasonable comfort. Glasgow was one of the first cities to realise the importance of conveying a supply of water from where it was abundant, and its housing estates were the envy of other cities. In transport, too, Glasgow had for long been in the forefront of progress.

The members appreciated the honour conferred upon the Institute by the attendance of the Lord Provost at the beginning of what would be a very strenuous period of his life. If he had been correctly informed, the Lord Provost was no stranger to hard work, and would therefore not be likely to fail in the task he had undertaken. He was determined that Glasgow should be kept in the forefront of rearmament work, and would see that Clydeside got its fair share. If the citizens did not live up to their responsibilities, then the city was not going to live. He had great pleasure in giving the toast, coupled with the name of Mr. P. J. Dollan, the Lord Provost.

Corporation as a Company

THE RT. HON. THE LORD PROVOST (MR. P. J. Dollan), in responding, said that he usually found, when attending a function such as this, that he had to be prepared with pocketfuls of Mills' bombs to throw at the proposer of the Civic toast! Nearly every citizen seemed to delight in deriding the city by pointing out all its defects, real or imaginary, and forgetting all its merits. He usually spent two minutes in demolishing the argument and convincing them that Glasgow was a place worth living in. Mr. Makemson had spoken the truth about things as he had found them, and for that he deserved a bouquet.

If the Glasgow Corporation were a company—and it was in fact the most important company in the city—he would be the chairman of a company having an enormous capital, with 47,000 employees, a wages bill of 7½ million pounds, and having had no strike of serious importance for the last 10 years. The people running Parliament and the cities were not to blame for the industrial position. If the chairmen and directors of industry had managed their businesses as well as the local authorities had managed theirs, there would not be over 2,000,000 unemployed people in the country to-day, and there would have been fewer bankruptcies during the past ten years.

Steel Houses

In regard to housing, there were undoubtedly many things to do, although they had built 47,000 municipal houses since the war, and rehoused a population bigger than the populations of Aberdeen and Dundee. He believed that the iron and steel industries were going to play a big part in the future, and that house building could be planned and carried out with the use of steel in much the same manner as motor-cars were built; the output could be increased by 50 per cent. and provide employment for building operatives for 10 years, but builders would have to abandon their conservative ideas and methods.

There was a great need for Glasgow getting a share of the rearmament work. He hoped that in two or three years 10,000 people could be employed in building aircraft in either State-owned or privately-owned factories. Government work in this direction was now assured, and he was confident that Clydeside could do as well in aircraft as in ships. He wished also to see something done for the semi-skilled tradesmen, the handymen of industry; there were 75,000 who should be enabled to earn their own living, instead of being condemned to an indefinite period of idleness.

Realism and the Pooling of Knowledge

SIR WILLIAM MARSHALL, in proposing the toast of the Institute, said that he had had a long association with the foundry industry, although not on the technical side. It was the basic industry on Clydeside, for shipbuilding and all branches of engineering relied on the efficiency and economy of foundry products. In industry to-day it was necessary to specialise in order to get the best work. Rule-of-thumb methods of the previous century were useless, and research was necessary in all directions. If the idealistic state of the 19th century was to be changed to the realistic state of the 20th, pooling of interests was essential. The industry had need of a technical society such as the Institute of British Foundrymen for the distribution of new discoveries. Papers should be given with the same freedom as in the medical profession for the benefit of all. He regarded the Institute as the best indication that British industry was keen for progress, but he had always believed that results depended not only on the efficiency but also the economy of the product. It was only by bringing down costs that the West of Scotland could get the prosperity it desired.

Record Membership

MR. H. WINTERTON responded in the absence of the President of the Institute, who had written a letter expressing his regrets at being unable to attend the dinner. He had pointed out that, if we wished to preserve our industries, we must develop the technical side. It was not a case of whether industry needed technical men, but whether industry could do without them. It was imperative that all the knowledge possible be obtained, and in this direction the Institute was giving great assistance. Mr. Winterton recounted the work of the founders of the Institute and the work of the latest Branch in South Africa. The total membership had reached the figure of 2,225 which was the highest yet recorded.

MR. A. L. MORTIMER, in proposing the toast of Technical and Educational Institutions, first dealt with the very close co-operation between the Scottish Branch and other technical societies in the West of Scotland. He mentioned that 30 technical institutions had made the arrangement whereby the membership of one permitted attendance at meetings of all the others. They also exchanged speakers on practical subjects, as well as holding joint meetings.

MR. A. C. GARDNER, in reply, said that discoveries were now so numerous that we were losing our sense of wonder at the effects of new inventions. Presently, perhaps, men would have the sense to learn how to control the things they had discovered.

MR. JOHN ROXBURGH, in proposing the Scottish Branch, said that Scotland being so famous in shipbuilding, and the foundry industry being essential to it, one naturally expected to find a strong Branch in Scotland. The Branch had over 300 very keen and enthusiastic members. The Institute had two outstanding features: it was of real practical value to its members and it was democratic, catering equally for the director and the operative. The Scottish Branch took a very important part in the Institute's activities, and the Council greatly valued the part the Branch played.

MR. ROBERT BALLANTINE (Branch-President) acknowledged the toast, and expressed pleasure at the record attendance at the function. He said that, whatever the Branch undertook, it was what they considered to be desired by the industry.

Sixty Years of Service

In connection with their silver jubilee, the firm of T. W. Ward, Limited, of Albion Works, Sheffield, and elsewhere, have issued an extremely handsome commemorative brochure. The reviewer must, like many other members of the foundry industry, regard this publication with a personal interest. One outstanding memory recalled was the recorded sale of a large shop, which was subsequently re-erected at Dunston-on-Tyne to house the first electric steelworks on Tyneside. It is interesting to notice that at the very inception of the company, the merchanting of foundry raw materials was started, and during the last decade this department, under the direction of Mr. Arnold Carr, has notably expanded. With the passage of time, the firm has *inter alia* become large foundry owners. The inclusion of a fine series of pictures of the various shops and important works which have been either broken up or dismantled makes the book of considerable historic interest, and one which will be highly valued by the searcher of industrial history in the future. Although the reviewer's association with the firm dates back some thirty years, he was unaware that the firm were old-established manufacturers of umbrella and walking-stick handles. The compiler of this most interesting brochure is to be congratulated on its lay-out and general production.

FOLLOWING the re-planning and reorganisation which has been going on at the Park Works of David Brown & Sons (Hudd), Limited, Huddersfield, for some time, the worm-gear drawing office, adjacent the main entrance, has been converted into an imposing and excellently appointed reception room. The display stands are representative of each division of the organisation, and the accompanying showcards and lists indicate the main products of each section.

Enamelling Troubles*

By S. W. VICKERY

There is probably no one more capable than the enameller to judge the amount of trouble caused in a plant from faulty or poor equipment. It is not deemed necessary to dwell on this point, beyond mentioning such examples as "scumming," which may be due to leaky furnaces, and the troubles that may arise on account of emulsified oil and water in the air-supply lines, and on account of inefficient driers. These and many other outstanding troubles confront every enameller, but most of the common variety can often be due to a change in material or to shop practice.

A certain technique best suited to the processing of any new part is adopted, often after many trials, and when trouble arises it can eventually be traced to the following causes:—(1) Improper cleaning of the metal either by pickling or blasting; (2) changes in the spraying, drying or fusing practice, and (3) changes affecting some small feature of the design.

Changes in Design

The following are two instances of specific troubles due to the change in design:—(1) Sheet-iron grill pans suddenly developed blisters around the underside of the bead, and upon investigation, it was found that the bead had been entirely closed on a new set of pans; the correction was obvious, though the damage had been done. (2) An almost similar case was a panel with a return flange developing hairlines in cover coat, due to the return flange being entirely flattened down.

Faults in Materials

The dangers of using unreliable materials are another source of trouble, as the following two instances show.

(1) Parts being enamelled with an acid-resisting enamel developed a severe pitting, and the enamel lost "set" rapidly. Check mills were put on using dependable chemicals, and a blank run with regular mixings. The results proved that the sodium aluminate used was of an inferior grade; the setting-up quality had been affected or lost through ageing. An investigation was carried out on several grades of sodium aluminate and it was found that many were inferior, even though the material was theoretically as good as a chemically pure grade.

(2) A sheet-steel cover-coat in a plant suddenly lost its gloss, and the firing temperature of the enamel increased with each successive milling. The trouble actually was that the enamel was being highly contaminated with porcelain from a new shipment of porcelain balls of cheap origin. A test was carried out, and it was found that the porcelain balls in question lost 1¼ lbs. in weight for every 100 lbs. of enamel milled.

Two instances of the more complicated types of trouble are detailed below.

"Copperheading" Developing on Sheet-Iron Ground-Coat

After making trials and thoroughly checking pickling and muffle practice and finding that this did not overcome the "copperheading" defect, a survey of the plant was made, and the following contributory causes were observed:—

First, there was a vapour degreaser very near the ground-coat processing. Vapour degreasers contain trichlorethylene, which tends to hydrolise and form some hydrochloric acid gas. This, of course, could accelerate rusting of ground-coated sheet-iron parts before they were fired and thus cause "copperheads."

Another source was found in some Bonderising equipment nearby, this making use of a solution of phosphates and phosphoric acid. It was also noted that when this equipment was not operating no "copperheads" appeared on the ground-coat. When final plant alterations were completed, the "copperheading" disappeared.

Flaking and Rusting of Castings in Service

The finished casting developed a flaking and rusting on the enamelled surface in some instances. This rusting caused failure of the enamel, whilst in others rust spots were found on the iron under the enamel that had not been fractured thereby. It has been suggested that this rusting may have resulted from moisture penetrating through from the back.

The analysis of the casting in question is:—Gr, 3.10; C.C, 0.17; Si, 2.63; Mn, 0.43; S, 0.088 and P, 0.83 per cent. Silicon is slightly higher than the usual range, and the total carbon is somewhat low. Manganese is definitely too low. The relatively high graphitic carbon and resulting low combined carbon indicate that the heat in enamelling has produced a rather thorough annealing, and that the iron involved was not particularly stable under heat. So much graphitisation would tend to promote porosity in the iron, in which the original graphite plates were large and tended to form an interconnecting network.

In preparing samples for metallographic examination it was noted that the casting showed considerable internal porosity. Examination by the naked eye and magnifying glass showed a definitely porous structure immediately beneath one of the rusted areas. Areas away from the rusted spots did not show this. Specimens were prepared at right-angles to the enamelled surface, cutting across areas that were rusted, also parallel to the enamel surface. Under the microscope, the unetched specimen parallel to the enamel surface showed a relatively fine graphite with considerable amounts of slag and porosity at the areas in question. A lesser amount of these defects were noted at other areas. The Nital-etched specimen showed a definitely dendritic structure with very fine graphite and large areas of ferrite and steadite. No definite pearlite grains could be detected. The defects which had been noted in the unetched specimen were definitely "slag lakes" and "pores." Again, they were more evident at the areas where the rusting had taken place. The specimens at right-angles to the enamel were not so definitely dendritic and the graphite was in whorls, and extremely porous. The evidence proves that this iron was not the best as to soundness; it was extremely porous, some porosity being visible to the naked eye. There was an abnormal amount of slag inclusions. It is obvious that the rusting was produced by moisture.

It is a known fact that relatively soft iron, when used in enamelled parts for steam jacketed units, suffers a structural breakdown by the heat of enamelling, producing local pressure failures of the enamel by steam penetration through the iron at relatively low steam pressure. It was, therefore, concluded that rusting beneath the enamel surface was due to penetration of moisture through the iron due to repeated heating and cooling in service and the sweating resulting from the condensation of moisture on the casting from gas fumes produced by the gas flames in the oven.

The remedy for this situation simply meant the closing of the grain of the iron by raising the manganese from 0.43 to around 0.70 per cent. This is an example of a trouble over which the enameller has no control at the time of happening and is an outside contributory source of trouble.

Fishscaling

Some time ago, the authors received several cases of a delayed fishscale defect. The defect became evident after a considerable time in service. Fishscale is generally attributed to many causes, but it is more readily defined as a local breaking down of adherence at the point affected. Knowing that there are many contributing factors brought into play, it is rather difficult to state conclusively that the clay, acid, neutraliser or steel caused the trouble. However, it was rather a coincidence that the parts affected nearly all fishscaled in a band 6 in. in from one edge; this fact led to the assumption that the pieces had received somewhat the same treatment, and there was evidence that it could be in the pickling.

In the efforts at the reproduction of the defect, it was never possible to say whether the area affected was that area which was exposed or unexposed to the full action of the pickling, that is, was the part affected overpickled or underpickled?

During the investigation, it was noticed that certain pieces had come into direct contact with the gas flame from the pickle room dryer. These parts, after standing in the normal shop atmosphere for three or four days, were badly oxidised over the area exposed to the gas flames, whereas the area which was unexposed to the flames was unoxidised, and appeared as if freshly pickled. These pieces have been processed as normal practice and no defect has yet appeared. However, it is felt that interesting information will be available on this subject at a later date. As a precaution the use of gas burners in the pickle shop dryer has been discontinued.

DISCUSSION

In opening the discussion the CHAIRMAN (Mr. W. S. Grainger) referred to Principal Edward's Paper in which the author showed the penetration of hydrogen through various gauges of sheet iron and its connection with pickling problems. He was also in agreement that moisture could penetrate castings from the back. This was very apparent in castings which had been in service and which had been enamelled with a matt ground-coat, there being no enamel on the back of the casting. He referred to the enamellers' trouble of "fishscaling" and suggested that the main contributing factor might be the enamel composition.

* Paper read before the Midland Section of the Institute of Vitreous Enamellers, at the opening meeting of the Session, held at the Imperial Hotel, Birmingham. Mr. W. S. Grainger presiding.

MR. H. A. BORE asked why steel sheets were rejected by some firms because of black specks developing on the finished product, yet the same steel was quite satisfactory in other plants.

MR. GRAINGER cited a test in which three different grades of sheets were processed at the same time, and only one showed the black specks referred to. In such cases the sheet must be a contributory cause to this defect. He agreed, however, that one could make an enamel to suit almost any grade of sheet, and it might be that the enamellers using the sheets satisfactorily were using an enamel of somewhat different composition.

Cause of Delayed Fishscaling

MR. SLAWSON suggested that delayed fishscaling was due to varying solubility of different materials. He suggested that a matrix was formed of silica and boric oxide and that other alkalis were suspended in this matrix (these remarks being based on the "random network" theory of constitution of vitreous materials). On weathering, solution occurred of the boric oxide and alkalis and left the silica. The small particles of silica were left on the surface of the ground-coat enamel, thus breaking the film strength, and they might be the cause of the enamel breaking down after a varying period and giving delayed fishscale. With regard to the statement often made regarding this defect only showing on occasional pieces, he suggested that two contributory factors were generally necessary to promote the trouble, and that if an enamel was of such composition as to make it on the border line towards fishscaling, then any slight variation in processing, such as pickling, drying, fusing, etc., would cause fishscaling. He felt that this should be seriously considered when attempting to find the cause of the defect. It was very difficult for every piece to have perfect treatment in practice, and with a border-line enamel the defect appeared on individual pieces.

MR. J. GARDOM was of the opinion that it was due to the varying expansion and oxidation of the ingredients. He said that an enamel was a mixture of various chemicals. These probably all went into solution, but it was not a stable one. It was possible for certain ingredients to separate out, and the difference in expansion or oxidation of these would weaken the enamel strength. He disagreed entirely that moisture would penetrate through the iron under the normal use, oxidise the surface of an enamelled article and push the enamel off.

MR. ENGLAND developed his theory of fishscaling as being a segregated solid surrounded by a mass of enamel of different expansion and advanced a few ideas as to how this solid might be developed. He pointed out that, generally, his experience was that people who made their own enamel did not take the same care in selecting their raw materials, *e.g.*, felspar, as did manufacturers of enamel. To a question as to why fishscaling occurred on the finished plate when the grip-coated plate was allowed to stand about before being sprayed in white, he advanced the theory that this, being relatively high in borax, the atmosphere might tend towards the solubility of the borax content, thus leaving minute masses of the other parts of the grip-coat, which would cause the effect under discussion.

Penetration of Cast Iron by Water Vapour

MR. J. FALLON said that some cast irons were porous and that all cast irons used in the enamelling trade would not withstand a petrol test. He was convinced that under service conditions water vapour could penetrate castings.

MR. GRAINGER replied that he agreed with Mr. Fallon and had seen tests which proved conclusively that water vapour could pass through the casting, but when the casting was enamelled both sides such a passage was discontinued and the trouble was not again evidenced.

MR. FALLON, after expressing his enjoyment of the informal but very satisfactory meeting, proposed a hearty vote of thanks to the Chairman, which was seconded by MR. ENGLAND.

Use of Metallic Abrasives

The Paper entitled "An Investigation into the Use of Metallic Abrasives," by Mr. J. E. Hurst and Mr. W. Todd, which was reproduced in our December 1 issue, resulted in a lengthy discussion when it was presented at the annual conference of the Institute of Vitreous Enamellers in London.

MR. W. THOMAS expressed thanks both to the two authors and their companies for allowing these experiments to be carried out. Such investigations, he said, interfered with ordinary works production and both companies were to be complimented on their public-spirited action in undertaking these experiments for the common good.

Erratic Results and Pre-Crushing Grading

He asked the authors, if possible, to give some explanation for the widely-differing values which appeared for No. 16 grit at the various stages of the experiment. For instance, the No. 16 grit at 6 hrs. represented 43 per cent., at 7 hrs. it fell to 36 per cent., and at 8 hrs. it fell to 20 per cent. At 13 hrs. the figure rose to 40 per cent., again dropping to 17 per cent. at 14 hrs. Did the authors consider that this irregularity was due to the fact that the experiments had necessarily been carried out on a works basis and not on a laboratory basis, and that in consequence the results were approximate? Or was there any change in the particular machine being used for the experiments—change of nozzle, for instance? He had taken the trouble to get out a graph and noticed that the alternate results for the No. 16 grit gave a reasonably continuous curve, whereas the results as given in the Table in the Paper gave a rather erratic curve. Unfortunately, in an experiment of this kind it was not possible to determine the actual weight of abrasive used up per hour, and his own curve suggested the possibility that when a particular piece of grit began to break up it did so very rapidly.

Following this line of thought, one wondered if grit made under certain conditions broke up before grit made under other conditions. Therefore, he asked the manufacturers of this particular grit if, when the metal was first cast, the round shot was graded and then crushed up into grit and re-graded, or was the shot crushed before any grading was attempted? In the latter case he could imagine quite a difference in results one might obtain from grit crushed from shot say, $\frac{1}{8}$ in. in dia., and grit crushed from shot say $\frac{1}{4}$ in. or $\frac{1}{2}$ in. in dia. He suggested that some of these results might be due to the breaking up of some particular size of original shot, which suddenly broke up and disintegrated, and that there were the other sizes of shot carrying on until a given time and then suddenly breaking up, giving a series of humps in the curve. From Table I it seemed there were three distinct humps.

Non-Magnetic Dust

There was one point of academic interest he would like to ask the authors. It was stated in one part of the Paper that "The amount of non-magnetic material in this dust varies in the samples from 0.5 per cent. to 6.1 per cent., the average over all the samples being 2.62 per cent. In other words, approximately 97 per cent. of this dust consists of metallic abrasive." He queried that assumption, because surely there must be a lot of material from the castings themselves and the dust could not consist purely of abrasives? Somebody might base future work on the figures given by the authors, and that was why he mentioned the matter.

Finally, Mr. Thomas asked if the authors proposed carrying on the experiments, starting, say, with heavier grit and seeing whether it kept its size for a certain period and then broke up rapidly, or whether at the same pressure it might break up to 16 or 18 grit and remain at that size until it broke up finally. Also, did the authors propose to experiment with other pressures? He felt that the pressure might have some influence. One other experiment he would like the authors to carry out was to determine at what rate any given grit should be added to keep the percentage grit size constant under varying conditions of pressure and original grit size. This, presumably, would be the ideal to be aimed at when working a shot-blast plant.

Cause of Irregularities

MR. J. E. HURST, replying, referred to Mr. Thomas's query concerning the irregularities in the individual results in Table I. The authors, like Mr. Thomas, had attempted to plot those results and had noticed the irregularities, and it was for that reason they had not included curves in the Paper. They attributed that irregularity to the manner in which they had been forced to take their samples. The samples were taken hurriedly and momentarily by hand out of the circulating stream. The nozzle was allowed to blow on the castings and a certain quantity was allowed to collect on the bench where the castings stood and the sample was taken. That was not a very satisfactory way of taking a sample, and he himself had attributed the irregularities mentioned by Mr. Thomas to that unsatisfactory method of taking the samples. So far, they had not discovered any better method of doing it with this particular machine. Mr. Thomas would no doubt bear in mind that each of these experiments made use of the same machine. The same shot was used; 5 cwts. in one experiment and 1 cwt. in experiment No. 2, and no shot from any other source had been introduced into the experiments, and no other machine was used.

What he personally had at the back of his mind in the experiments was in the ultimate to attempt to devise a test which could be made to measure the efficiency of grit. He had been wondering whether it would not be possible sooner or later in his laboratory to have a small duplicate of a shot-blasting machine, such as the one used, in which he could put shot through in a circulating load under controlled conditions and use that as a method of measuring the efficiency, in its broadest sense, of grit, because at the moment there was no real tangible way of dealing with the testing of grit in that way. That was another reason why he valued Mr. Thomas's remarks, because, if ever he got to that stage, he felt certain he could carry on the additional experiments in the manner suggested.

In connection with larger shot, the authors had not made any experiments. The experiments described in the Paper were the only experiments they had done so far, but it would be interesting to adopt Mr. Thomas's suggestion and repeat experiments of this type with larger shot and see what happened and how that shot broke up. Obviously, there were various factors to be taken into account from the enamelling side. There was a limit to the maximum size that could be used. He imagined the enamellers would have something to say on that. There was also a limit to the maximum size shot the machine would lift.

Personally, he did not wish to let this matter drop, and would like to continue the experiments, as he felt they should lead to something useful for the whole industry, both the manufacturing industry and the shot industry.

Size Control Before Crushing

This reminded him of the other point mentioned by Mr. Thomas, *viz.*, the original size of the blown material from which shot was made. As manufacturers, his firm attempted to control the size of the blown material prior to crushing. They separated out and crushed a definite range of size of the blown material. Naturally, the size of the material blown varied quite a good deal, but the endeavour was made to control it and keep it within as narrow limits as possible.

Nomenclature

MR. J. G. PEARCE (British Cast Iron Research Association) said that three points occurred to him. In the first place he had seen the samples from which Figs. 5 to 9 had been taken, and could assure those who had not seen them that, difficult as it was to represent the effects in a black-and-white photograph, the effect was undoubtedly there, and it would be very important indeed if enamellers with practical experience could confirm or otherwise the idea that round shot did give these troubles of specks on boiling, as a general thing. He did not know whether that was an accepted fact in the industry.

His second point raised the question of a standardised nomenclature for these things. In discussions almost weekly in the Press,* this process was referred to as a sand blast or shot blast. If there was a difference between grit and shot it was important to make the distinction, and refer to the use of either chilled grit or chilled shot, whichever was appropriate to the material under review. The term "sand" should be dropped where sand was not intended, and they should also drop the term "steel shot" for what was obviously chilled white cast iron.

The third point was that, from Table III, it appeared from the experiments there was no degradation in the shot as the experiments proceeded, but there was an increase in the amount of material rejected as the test went on. In Table I, apparently the actual rejects at each stage were not taken, and he would like to know if Mr. Hurst had any idea whether there was an increase or a fairly uniform rate of rejection throughout, because if there was an increase it rather suggested that the cleaning was good as long as further fractured surfaces of degraded pieces could be presented to the surface of the cast iron, and that that fragmentation might be an actual advantage in practice. It might be a perfectly sound thing to use round shot and break it up before it actually reached the user. Therefore, he would like to know if Mr. Hurst had any idea whether the rejection in Table I was relatively uniform or tended to increase as the experiment proceeded.

Rejection of Dust Grades

MR. HURST remarked that he ought to have said in giving the Paper that the British Cast Iron Research Association had been very good in assisting in the preparation of the three last photographs. It was, indeed, recorded in the Paper that both Mr. Todd and himself and the Institute as a whole appreciated the assistance which the British Cast Iron Research Association had so freely given.

Continuing, Mr. Hurst said this question of the rejection of the dust grades from the circulating stream was one about which Mr. Todd and himself had tried very hard to get some information but unfortunately they were unsuccessful. They had tried very hard to collect the whole of the rejected material from the dust separator at each stage of sampling, with the object of weighing the total amount of dust and also to get a better sample. Unfortunately they were unable to do this, so that he could not definitely answer Mr. Pearce's question. Mr. Todd and himself were hoping to make another test and perhaps get some better results from that point of view. It was quite possible that they might devise some experimental procedure that would enable them to do this. He would like to add his plea to that of Mr. Pearce for some attempt to standardise the nomenclature in connection with the blasting process. Whether it was a matter for the Institute to do something and take the lead, he did not know, but it would be very useful. At present, the nomenclature was definitely confusing, but sand blasting was a common term still used for this operation, although the expression "metallic abrasive" was also used. The authors had tried to establish the use of the terms "shot" and "grit," "shot" to be confined to the round material and "grit" to be confined to the crushed material, but he was in strong sympathy with the other suggestion of Mr. Pearce that the words "steel abrasives" should be abandoned because the material was chilled cast iron. So far he had not come across any commercial samples of grit or shot which were anything but chilled white iron, and it was wrong to perpetuate an error of that sort.

Metallic Content of Dust

He had been reminded by the chairman that he had not dealt with the point mentioned by Mr. Thomas with regard to the metallic material in the dust grade. It was stated in the Paper that approximately 97 per cent. of this dust consisted of metallic abrasive, but in the interests of accuracy he would have no objection to the word "material" being substituted for the word "abrasive." At the same time, he asked them not to assume that there was a vast amount of material. He doubted very much whether the actual amount of the dust grade was much more than 2 per cent.; that was the amount of material in the metallic portion which was not abrasive, but in the interests of accuracy he would have no objection to the change of wording he had mentioned.

Relation to Processing

MR. J. H. GRAY said that one thing which should be considered in connection with shot or grit was the efficiency from the enamelling point of view as well as the efficiency from the life point of view. A little while ago he carried out some experiments as the result of a discussion in which it was suggested that much better results were obtained with acid-resisting enamel by using flint grit, and this had made him wonder whether better results could be obtained by using metallic grit of various grades. Therefore, he carried out a number of experiments using the same acid-resisting enamel with different grades of metallic grit from 12 up to 20, and it was definitely proved that the 12 and 14 grades gave the best results. Although No. 16 might be the most efficient from the life point of view, Nos. 12 and 14 were definitely the most efficient from a processing point of view. The conclusion was arrived at that a larger grade should be the most efficient and it was found that flint was a larger grade than the most popular metallic grit (Nos. 16 and 18). It had a longer cutting edge as compared with metallic grit and did not ball up in use. It merely broke up and the cutting edge might vary from $\frac{1}{8}$ in. down to $\frac{1}{16}$ in., but there was always a continuous cutting edge.

Influence of Works Conditions

MR. S. HALLSWORTH said he had not desired to make an admission of weakness from the makers' point of view and had been waiting for someone to get up and criticise certain points. In his view, the author had been too honourable, and he personally felt that he ought to explain why. He did not think that too much notice should be taken of experiment No. 2 in Table III, because that experiment was carried out under conditions which were not quite satisfactory. It was carried out as a works test and not strictly as a research test. The test was carried out during the day time in the works and in a blast room there were many small stoppages. Moreover, in the case of the first test, there was a very dry atmosphere, but in the second test the weather was rainy and the blast plant was not then operating under the best conditions. Further, there was a lot of water under the foundations and the shot was rather damp each morning, and the result was that the man in the blast room gave the castings more blasting before he sent them out as being properly cleaned. That was why there was a larger consumption of grit during the second test than during the first test. It was true that this did not explain the variation in grade size, but at the same time he felt that the first experiment was the one which should be regarded seriously and the second experiment should not be taken seriously at all. Quite frankly, he would have liked to see experiment No. 2 eliminated from the Paper, but Mr. Hurst said that the test had been carried out and the figures should be given.

Replying to Mr. Pearce on the question of rejects, Mr. Hallsworth said that the rejects increased in the first experiment in a similar manner to the second experiment, although it was not shown in the Paper.

Graphite Smudges

MR. HURST said that probably the most important thing of all was the graphite in the circulating grit. The Americans, and even overselves, had had much to say about the graphite smudge which was obtained on castings after blasting with grit, but which was not seen with flint blasting. In all these tests, however, there was very little graphite carried on the surface of the grit, as shown by analysis, and yet the Americans particularly often stated that the chilled iron grit took up graphite and carbon from one casting and deposited it on another. It had not been possible to get hold of any, but at the same time it was difficult to explain why there was a black smudge on the surface of the casting after grit blasting. Perhaps someone could say what that was.

Flint and Metallic Abrasives

MR. A. ENGLAND referred in the first place to the question of Mr. Gray's experiments and comparison between flint grit and metallic grit and the alteration of the edges. It must be remembered that a metallic grit tended to round on the edges, whereas a flint grit did not. It split and always left the same cutting edge.

As regards the smudge mentioned by Mr. Hurst, personally he did not think that the smudge was graphite at all. He had carried out experiments a few years ago, and believed that the smudge which was obtained then was very finely divided iron, because it would be found that, unless the smudge was taken away, immediately the wet enamel was put on there was a tendency towards rusting, and that would not be so with graphite.

With regard to flint, most enamellers believed, whether correctly or not, that flint gave better surfaces than metal in blasting. It would have been interesting if Figs. 5 and 6 could have also been shown when done with flint, just to see the comparison and how it looked alongside the results with round shot, and also if it gave any guide as to whether it would be wise to alter the grade and whether thereby a similar result would be obtained, or whether a better result was obtained with flint than with metal.

Referring to the photographs comparing different enamels, he said he did not like these being done in mottled enamel, because he did not think that gave the best chance. A white enamel or

* The FOUNDRY TRADE JOURNAL for several years has been meticulously correct in the use of the terms shot blast and chilled iron grit.—EDITOR.

a slightly coloured enamel would perhaps have shown better what was wanted. However, he greatly appreciated the attempt of the authors to reduce blasting to a mathematical form.

Peening and Gas Accumulation

MR. R. W. WHITTLE said the use of the word "peen" in the Paper reminded him of some experiments he carried out a few years ago. When peening a surface of iron with anything round, the surface was stretched, and there was the likelihood of an accumulation of gas forming which, when heated upon the casting being put into the furnace, would blow off the enamel. He suggested that the black smudge to which reference had been made was the result of peening, which stretched the surface of the metal and permitted the formation of gas and the blowing off of the enamel. Therefore he submitted that by peening they were introducing a space for gas to accumulate which would give trouble ultimately.

Standardisation of Size Tolerances

MR. KENNETH HILL asked whether an explanation could be given of the mesh tolerances which were observed when the 5 cwts. of No. 16 angular grit was used in experiment No. 1, because in his view the original screening was of great importance. He also wished to make a plea for a better description of the grades of abrasives which were generally used in this country. People said they used No. 16 or No. 12 and did not really know what they were talking about, because this was only the number which applied to a particular make of grit, and it was not a number which could be accepted generally for that size of grit. Therefore, there should be co-operation among both users and manufacturers to obtain grades of abrasives which would be definitely within certain tolerances, so that the purchaser and the seller would both know exactly what they were buying and selling.

MR. HURST replied that B.S. sieves were used, and the sieve numbers were British Standard numbers.

MR. HILL said he was talking about the original material put into the plant, and wished to know the screen tolerances.

MR. HURST said the grade analysis was given in the Paper. No. 16 was a usual description. In experiment No. 1, it was stated that No. 16 consisted of 40 per cent. B.S. sieve 16, 14 per cent. B.S. sieve 18, and 40 per cent. B.S. sieve 24, with a small quantity above and below.

MR. HILL: Is that the standard?

MR. HURST: I am not aware of any standards.

MR. HILL: That is what I am requesting information about.

MR. HURST: I am not aware of any standards in existence.

MR. HILL (continuing) said there was also the point which had already been mentioned of the difference between flint grit and metallic grit, and it should be recognised that flit had cleavage.

A matter upon which he would like further information was with regard to the wearing of the nozzle and the type of nozzle used in these experiments. If the nozzles were of white iron, he imagined that at the pressure used they would be useless at the end of 8 hours. On sand-blasting machines the adjustment was such that an unvarying flow of abrasive was introduced into the air stream, but if the air was increased with the same amount of abrasive passing through, there would be a diminution in the area cleaned. Therefore, he would like to know what type of nozzle was used. Was it white iron or one of the new types?

MR. HURST replied that the nozzles were white iron, $\frac{5}{16}$ in., and they were changed when they wore to $\frac{7}{8}$ in. That had to be done after about 7 hours.

Technical Expansion

MR. J. W. GARDOM said he felt that the Institute should take part in some research and investigational work of this nature in order to reduce matters to a common basis. The discussion had brought out many different points of view, and he was convinced that the Institute would be well advised to put all its work on a definite technical basis, if it were possible. Mr. Hurst had said that his main object in giving the Paper was to find a test for his own particular product, which was metallic grit, but personally he would like to get something basic in all items, from the moulding sands in which the castings were made, and through all the remaining stages, and having put all this on record they should then try to do what Mr. Pearce had suggested, *i.e.*, to arrive at a nomenclature which everybody would use. For instance, reference had been made to chilled white iron. Did that mean iron that was white before it was chilled or was white after it was chilled?; there seemed to be a point to be settled there.

Costs

Dealing with some of the experiments, Mr. Gardom said his special interest was in costs, and in the work with which he was connected he had been looking very seriously recently into costs in relation to sand blasting or shot blasting or metallic abrasive blasting. All three terms were used for the purpose. This work concerned steel castings and had nothing to do with vitreous enamelling, but he was very surprised, when making use of different air pressures, to find that a lower pressure down to 40 lbs. was very much more an economical proposition, although the plant in which it was used was an old stand-by plant. Although, like Mr. Thomas, he would like to see these experiments carried further, using different pressures of air, etc., at the same time he suggested that this Paper was sufficiently good to be put before all the Sections for further discussion. From these further discussions a Committee might be formed, and in that way it might be possible to get down to a basis for any future work of the kind which might be done, and at the same time an effort should be made to standardise nomenclature.

Reverting to the question of cost, Mr. Gardom said that in experiment No. 1, 78 lbs. of grit were used per ton of castings cleaned, and in experiment No. 2 the figure was 110 lbs. He had divided that up in all sorts of ways to try to find out where the authors had lost some money, and the only thing he could see was that in the second experiment the time was 52 hrs. whilst in the first experiment it was only 39 hrs. Table I also showed very clearly that after 30 hrs. there was a serious breaking down of the grit. The Paper gave a photograph of a grit sample after 28 hrs.' use, but he would very much like to see a photograph of the grit sample after 39 or 50 hrs.' work. These photographs—and he would like to congratulate whoever took them, for they were excellent—showed that the grit was not really broken up but, at the same time, Table I more or less suggested there was no serious breaking up of the grit until after 30 hrs. The Paper only showed the position up to 28 hrs. If that were true, the second experiment which was carried to 52 hrs. explained the reason why that experiment cost more, *i.e.*, they had not cleaned as many castings with the grit.

Pitfalls in Standardisation

With regard to grit grading, which had been mentioned by Mr. Hill, he himself had done some work on this and knew how very difficult it was to repeat a grading and be certain it was the same as before. The British Standards Institution had already done good work in standardising sieves, but he suggested that they should all go very carefully before talking about standardisation in this matter, and that they would be running into trouble if they said to a buyer that he was getting grade 16 which contained 60 per cent. of 16 grade, because the buyer would probably re-sieve it and send it back and say it contained only 58 per cent. Therefore, he asked them to keep that carefully in mind on both sides. It was clear that further work on the question would be of great value and benefit to the trade.

Finally, Mr. Gardom commented on the remarkable cleanliness of the shot used in the experiments described in the Paper and said the authors must have an exceptional exhaust system. He doubted whether all works had such a satisfactory exhaust system.

Nozzle Variations

MR. W. T. HODGKINSON remarked that, having done some experimental work on Brinell hardness testing and other testing, he felt that a test of the type indicated by the authors would be more useful. In doing any kind of experimental work it was always necessary to bring down the variables to as few as possible. With regard to operators, Mr. Hurst stated that the same operator carried out these experiments, although it had occurred to him that as the test was for 40 hrs. duration there might have been different men engaged on the work. It might not be generally known that there was a difference in shot work depending on the angle at which the jet was presented to the work. In other words, if it was normal to the work, the shot would break up more readily without being so effective in cleaning the casting. Another feature which made shot break up quickly was the surface hardness of the casting to be cleaned. Apparently in the authors' case the castings were some part of cookers and the surface hardness would be fairly uniform. Yet another point was the pressure, and it was necessary to realise that in the case of some nozzles the aperature enlarged rapidly and brought about a reduction of air pressure. The velocity of the air leaving the jet did not vary very much over a wide range, but the density of the air would vary and there might be greater slip between the shot and air following a drop in pressure, so bringing about a reduction in speed of shot, although the actual velocity of the air leaving the jet did not fall very much. That was a point which might bring about a change, and if this test was carried out again, it might be carried out with a "Norbide" nozzle which maintained its aperture for a long period. At the same time, he suggested that if the angle at which the jet was held relative to the casting could be a fixed angle, it would eliminate another variable. When a man was doing this work manually, there might be considerable difference in the results. Further, this test was carried on for 40 hrs., and he assumed it was not a continuous test. It had evidently been done during the daily routine, and that might also have some effect, and be responsible for differences in the experiments.

Crushing Deterioration

In the manufacture of grit, he had found that if a crushing plant was run for long periods, the output went down. Whether that was due to any temperature change in the material or to change in surface hardness of the crushing rolls, etc., he was not quite certain. Another thing was that these experiments had been carried out in a room. It was stated that the room had been swept out at the beginning, but there was no reference to whether the room was swept out during any part of the experiment, or whether it was swept out at the finish. It was possible to get very considerable differences in the percentages of the sizes of the particles of abrasive at the finish if the room was completely swept out. He was also wondering if the authors thought the breaking down of the shot might be due to fatigue. The influence of heat at even small temperatures could bring about a change, and he had heard of such effects even at temperatures as low as 100 deg. C. Therefore, fatigue and heat might have something to do with it.

With regard to the tests on round shot, he was surprised to find that shot of such small size as 30 was tried. References had been made to larger pieces of flint grit. The work done by a

particle of grit depended on the kinetic energy of the particle, and as flint was very much less dense than metallic abrasives, the flint particle had to be larger in order to possess the same kinetic energy as metallic abrasive at the same speed.

Standardising Sizes

If there was a mesh of a given aperture and the same wire was put on the four different types of machine, *viz.*, the sieve, the rotary screen, the plan sifter and the vibratory sifter, there would still be differences in the results. Also with the same aperture on the different machines, but with different gauge wire, the results would again be different, so that it was very difficult to standardise sizes. Moreover, he did not believe that the majority of users realised how difficult it was to keep within a band of sizes without having too much wastage.

The CHAIRMAN said that although the authors at the end of the Paper thanked all those who had helped in this work, he was sure the meeting would like to endorse that vote of thanks. Continuing, he said the discussion had clearly shown the necessity for such research, and to bring in some form of standardisation not only in nomenclature but in other directions. He was sure the Council of the Institute would, through its Research Committee, working with the British Cast Iron Research Association, endeavour to come to some decision on this point. Finally, the Chairman expressed the cordial thanks of the meeting to the two authors for having given such an interesting Paper and provoking such a useful discussion.

MR. HURST said that for his part he felt it was a great privilege to have been allowed to present this Paper, and he was certain that, when he told Mr. Todd what a good reception the Paper had received, he would be delighted to collaborate further with a view to continuing the experiments on the lines which had been indicated in the discussion.

MR. J. T. GRAY suggested that the Institute should appeal to the manufacturers of crushed metallic grit, as he preferred to term it, to get together and arrive at standards among themselves for some method of testing, so that if an enameller bought 16 gauge from more than one manufacturer he got as near as possible the same size. At present what was 16 gauge to one manufacturer might be 12 gauge to another. Indeed, that was an actual fact in practice.

Consistency of Enamel Frits at and near Firing Temperatures

By WILLIAM N. HARRISON, ROBERT E. STEPHENS and STEPHEN M. SHELTON

(*Concluded from Vol. 59, p. 260.*)

Frits of Complex Consistency

The speed-deflection curves for acid-resisting cover-coat frit 6, shown in Fig. 5, are so nearly straight at several temperatures that no curvature could be detected with certainty. However, in the results obtained at 893 deg. C., and to a greater extent in those obtained at 934 deg. C., a definite curvature is apparent, indicating that the material is not a simple viscous liquid. Inasmuch as there is no evidence that any of these curves fail to pass through the origin, it may be said that at these temperatures frit 6 behaved as a complex liquid, sometimes called a non-Newtonian liquid.* Each curve in Fig. 5 has been labelled with a number indicating the average apparent viscosity.

Fig. 6 shows the data for ordinary sheet-iron cover coat 25. All of the speed-deflection lines in this graph are definitely curved except that obtained at 750 deg. C., and the nature of the entire chart suggests that curvature would be apparent at this temperature, too, if rates of shear as great as those reached at higher temperatures had been attained. In Fig. 6 and all succeeding figures, broken lines have been superimposed on the charts. These lines show the positions on the graphs corresponding to various viscosities. Wherever the curves cross these lines, the apparent viscosity of the sample at the indicated temperature and speed of rotation was equal to that indicated by the broken line. The apparent viscosity for any point on any data curve can be read by simple interpolation between two broken lines, in a direction parallel to the ordinate.

Very opaque frit 35, the results for which are shown in Fig. 7, displayed a marked departure from simple viscous consistency. For example, at 887 deg. C. the apparent viscosity at a speed of 0.0028 r.p.s. was nearly 6,000 poises, whereas at the same temperature the apparent viscosity at 0.060 r.p.s. was less than 2,000 poises.

Dry-process leadless frit 65, data for which are shown in Fig. 8, gave speed-deflection lines of even greater curvature than those of frit 35. At 936 deg. C., for example, the apparent viscosity at a speed of 0.0042 r.p.s. was 2,600 poises, whereas at 0.0696 r.p.s. it was only 536 poises, or approximately one-fifth as much. Nevertheless, the results were quite systematic, and gave no indication that any of the curves failed to pass through the origin.

Comparison of the apparent viscosities of frits 6, 25, 35 and 65 at stated temperatures must be made either at constant speed of rotation or at constant torque. Since, in practice, the force tending to make the enamel flow during firing would presumably be more nearly constant than the rate of flow, comparisons at constant torque were considered preferable. In Fig. 4 the apparent viscosities of these frits, at a viscometer deflection of 10 units, is plotted against temperature together with the viscosities of ground coats 1 and 11.

Fig. 4 (see the first instalment of this article) shows that acid-resisting sheet-iron frit 6 had the highest resistance to flow of all the frits shown. Its curve for log viscosity against temperature is almost parallel to that for ground-coat frit 11. At equal temperatures frit 6 was, however, about 3 times as resistant to flow as ground coat 11, and about 10 times as resistant as ground coat 1.

The ordinary sheet-iron cover coat 25 was about as resistant to flow between 800 and 850 deg. C. as ground coat 1, but below this temperature range it was more fluid, and above, less fluid than the ground coat.

The consistency of the very opaque sheet-iron cover coat 35 was so complex that a graph of apparent viscosity, at any selected torque, against temperature has questionable significance. Fig. 4 does show, however, that the apparent viscosity of this frit is within the range found for other enamel frits, and is in the high-viscosity part of this range, between the temperatures of 850 and 950 deg. C., within which zone it probably would be fired.

The significance of the curve relating log apparent viscosity of enamel frit 65 to temperature, at constant torque, is also questionable. However, this curve indicates that the apparent viscosity was in the lower part of the range covered by the entire series of frits, and appears similar in trend to the curve for frit 35, but shows equal apparent viscosity at about 60 deg. C. lower than frit 35. There are no data to show whether the curve for frit 65 would curve upward at temperatures below 740 deg. C., thus carrying through its parallelism to the curve for frit 35. This temperature was considered safely below the probable firing temperature of actual practice.

Frits of Erratic Consistency

Frit 72, a high-lead composition for use with added stains to produce various colours in the wet-process enamelling of cast iron, and number 85, a lead-bearing dry-process frit, were found to have consistencies which can well be described as erratic. These are the only lead-bearing frits studied. The data are shown in Figs. 9 and 10, respectively. It may be seen in Fig. 9 that frit 72, at 780 deg. C., decreased

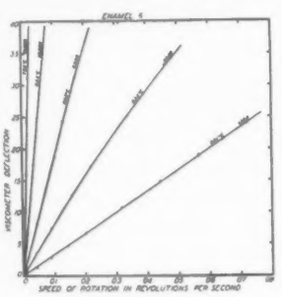


FIG. 5.

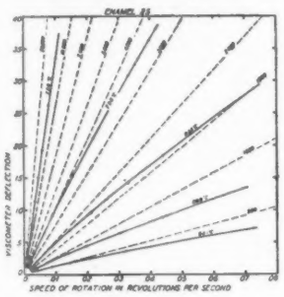


FIG. 6.

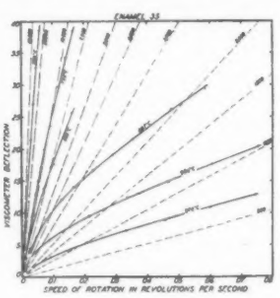


FIG. 7.

FIG. 5.—CONSISTENCY OF ACID-RESISTING SHEET-IRON COVER-COAT ENAMEL FRIT.

The curved lines, apparently intersecting the origin, indicate complex, or non-Newtonian consistency. The numbers following "deg. C." indicate average apparent viscosity in poises.

FIG. 6.—CONSISTENCY OF "ORDINARY" SHEET-IRON COVER-COAT ENAMEL FRIT.

The shape of the speed-deflection curves indicates a complex consistency. The dashed lines show the positions on the graph corresponding to the viscosities, in poises, indicated by the adjacent numbers.

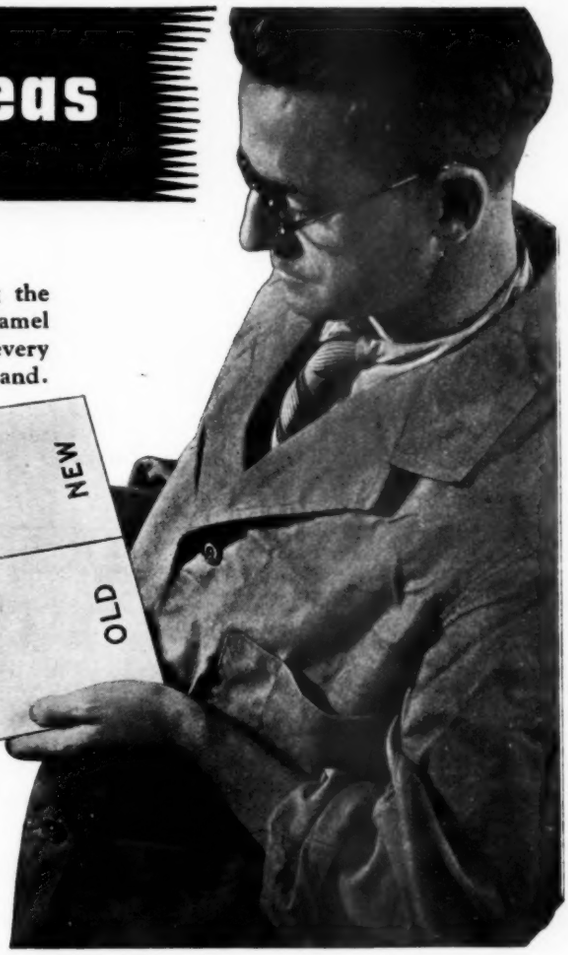
FIG. 7.—CONSISTENCY OF A VERY OPAQUE ENAMEL FRIT FOR SHEET IRON.

The marked curvature of the speed-deflection curves, which appear to pass through the origin, indicates a complex consistency. The dashed lines show the positions on the graph corresponding to the viscosities, in poises, indicated by the adjacent numbers.

* For pertinent definitions, see Proc. A.S.T.M., part 1, **34**, 1245 (1934). With the method of plotting adopted, a straight speed-deflection line passing through the origin denotes a simple viscous liquid, while a curved line, also passing through the origin, denotes a complex or non-Newtonian liquid.

The secret of Blythe reliability

as like as two peas



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gradually in apparent viscosity with increased speed of rotation up to 0.0046 r.p.s. Further increase of speed up to 0.0058 r.p.s. gave no increase in deflection. Additional increase in speed gave a more rapid decrease in apparent viscosity than occurred at lower speeds, followed by still more rapid decrease with higher speeds. Although not exactly reproduced, the general shape of this curve was established by several tests at approximately this temperature. The kink in the curve, which occurred at speeds around 0.005 r.p.s., did not appear to be caused by experimental error. The first data in Fig. 9 were taken at 927 deg. C. and the last at 930 deg. C. It is seen that the latter curve is smoother and is more definitely pointed toward the origin.

Fig. 10 shows not only the erratic nature of the relation between temperature, speed of rotation, and apparent viscosity of frit 85, but also its instability under the conditions of test. The data were taken in order of decreasing temperature except that after the test at 736 deg. C., a second test at 835 deg. C. was made. The second test at this temperature showed lower apparent viscosities and a speed-deflection curve much more typical of other frits than that obtained in the first test at 835 deg. C. This was the only frit for which curves obtained at substantially different temperatures actually crossed.

The data obtained on these two frits are not suitable, on the whole, for representation in Fig. 4. Nevertheless, one point from Fig. 9, namely, the apparent viscosity of frit 72 at 839 deg. C. and at a deflection of 10 units on the viscometer, has been placed in Fig. 4. The apparent viscosity of this composition, under the indicated conditions, is less than half that of frits 1 and 25, which are next higher. The average of the two curves for frit 85 at 835 deg. C. and 10 units of viscometer deflection corresponds to an apparent viscosity somewhat greater than that of frit 65 under the same conditions.

Conclusion

It should be pointed out that while the two ground-coat frits, because of their simple viscous consistency, gave results which may readily be discussed and compared, several of the other frits gave the reported results only when they were tested in the particular manner described. Thus, frit 35 gave the results shown in Fig. 7 when the viscometer speeds were successively increased at given temperatures, but when returned to a given speed of rotation following a test at a higher speed, this frit gave first a smaller and later a greater deflection than the original apparent equilibrium value. This phenomenon may be a manifestation of thixotropy.* Frits 6, 25, 65, 72 and 85 behaved, in part, like frit 35, that is, when re-tested at a given speed of rotation after a test at a higher speed, they gave different deflections than originally. It was thought that the procedure used, namely, to obtain values at successively increased speeds for any one temperature, was the one likely to yield values for consistency which would prevail in practice during the firing process.

Frit 85 appeared distinctly unstable, and some instability was also noticed in frits 35 and 72. In spite of these peculiarities of behaviour and the complex consistency of the cover-coat frits, some interesting comparisons may be made.

It so happens that the temperature 839 deg. C. (which is the only temperature given for frit 72 in Fig. 4) is within the usual range of firing temperatures of enamels, and a comparison of the different frits, under constant torque, at this temperature, is of interest. The figures are given in Table III. It is seen that under the indicated conditions the resistance to flow of acid-resisting frit 6 is over 28 times as great as that of frit 72 and over 12 times that of frit 25.

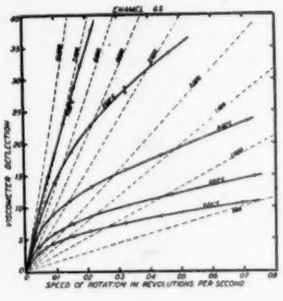


FIG. 8.

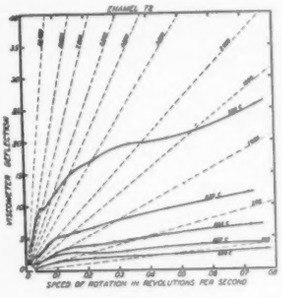


FIG. 9.

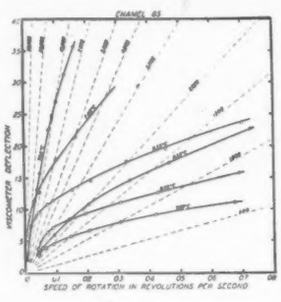


FIG. 10.

FIG. 8.—CONSISTENCY OF A LEADLESS DRY-PROCESS ENAMEL FRIT.

The sharply-curved speed-deflection lines indicate distinctly complex consistency. The dashed lines show positions on the graph corresponding to the viscosities, in poises, indicated by the adjacent numbers.

FIG. 9.—CONSISTENCY OF A HIGH-LEAD WET-PROCESS CAST-IRON ENAMEL FRIT.

The curves show marked deviation from simple viscous consistency, and the one for 780 deg. C. shows also an erratic shape near 7,000 poises, apparent viscosity. The dashed lines show positions on the graph corresponding to the viscosities, in poises, indicated by the adjacent numbers.

FIG. 10.—CONSISTENCY OF A LEAD-BEARING DRY-PROCESS ENAMEL FRIT.

The shape of the curves indicates marked deviation from simple viscous consistency. The facts that some of the curves cross each other, and that two tests at 835 deg. C. taken at different times on the same sample did not agree, indicate an unstable consistency. The dashed lines show the positions on the graph corresponding to the viscosities, in poises, indicated by the adjacent numbers.

TABLE III.—*Apparent Viscosities of Eight Enamel Frits under a Chosen Torque at 839 deg. C.*

Frit.	Apparent viscosity.	Frit.	Apparent viscosity.
	Poises.		Poises.
72	750	85	4,140*
1	1,660	11	6,460
25	1,740	35	7,760
65	3,390	6	21,380

* Estimated average.

If it be assumed that 4,000 poises is representative of the viscosity (or apparent viscosity) of enamels at firing temperatures, a rough estimate of the firing temperatures required to obtain this consistency may be made for six frits from Fig. 4, in which the appropriate ordinate (log viscosity) is 3.60. Enamel frit 25 attains this apparent viscosity at 795 deg. C., "hard" ground coat 11 at 860 deg. C., and acid-resisting frit 6 at 928 deg. C. Thus, frits 25 and 6, in which the apparent viscosity differs by a factor

(*Concluded on page 20.*)

* Thixotropy may be defined as the tendency of a material to form a relatively stiff structure when not disturbed, which breaks down and gives place to a more fluid consistency under agitation. See E. L. McMillen, "Effect of Thixotropy on Plastic Measurements." J. Rheology, 3, 185 (1932).

Early Iron Industry in South Yorks

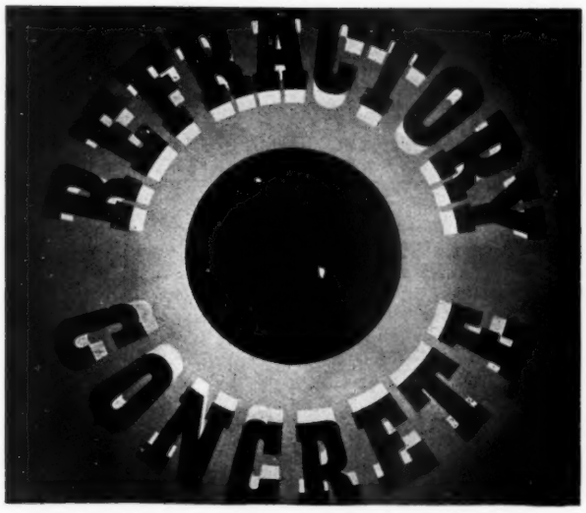
At a meeting of the Newcomen Society, held at the Iron and Steel Institute, London, on December 14, DR. A. RAISTRICK read a Paper on the "South Yorkshire Iron Industry, 1698-56," based on some manuscript material found a few years ago, and which is now the property of the Bradford City Museums and Library Committee. We append some extracts relating to iron smelting.

The furnaces are described as follows: A square masonry shaft, about 20 ft. wide and 20 to 25 ft. high, is carried at the base on arches usually on two adjacent sides. The shaft is made of roughly squared masonry and strengthened by at least four iron bands or girths that surround it at regular intervals. The hearth or hearthstone is of carefully chosen firestone sill, *i.e.*, a fire-resistant sandstone, often brought from a distant quarry, and is built up of a few carefully shaped and tooled pieces; it is about 25 in. or more square outside, up to 5 ft. high, and squared inside to 18 or 20 in., forming the effective "crucible" of the furnace. The top of the square hearth is carried upward by rapidly widening "boshes" for about another 3 or 4 ft., in which the section changes from square to round, the inside diameter being from 3 ft. to 5 ft. maximum at the top. The inside of the furnace shaft or "tunnel" has a brick lining, carried on the boshes, and eventually tapering or being corbelled off to the tunnel mouth, 20 or more in. diameter. Poorer quality stone and earth was packed between the outer case and the lining.

The hearth, it is stated, has a casting and working opening at one side, under the front arch of the furnace, and this opening is partly closed by two stones. The top one which really continues the boshes line is the tymp stone, and forms the upper lintel of the working hole or fire hole, while the bottom one is a separate sill of firestone, triangular in section, and is called the dam stone. This closes the bottom part of the hearth, and is set down in clay luting, but has under one end a deep groove which serves as a tapping hole. The dam stone is backed on the outside by clay and stones, as it has to act literally as a dam to hold back the molten metal in the bottom of the hearth. As the metal rises, the slags are skimmed off the top, over the sill of the dam stone. The furnace has a tuir set in a side arch, and usually made of a selected clay, "Clay for Twear, getting and leading, 6s. 3d."—in later years brought from Staffordshire, along with brass pipes from Birmingham, invoiced as for the tuirs. In front of the working arch is the casting floor of coarse sand, in which moulds of riddled fine sand are made. The sand is brought from a distance, and considerable renewals, 40 loads or more, made each year.

Ancillary plant seemed largely to consist of bellows, "usually in pairs, with nozzle pipes converging on the tuir hole in the furnace." Power was by "water wheel having a 'drum' shaft with 'nogs' which depress the bellows alternately."

Concerning forges and their equipment, it is recorded that "the forges were mainly placed on the banks of rivers with a considerable volume of water, as they needed more power than the furnaces. It was customary to employ several water wheels to supply power to the trip hammers and turn the slitting mill rolls in addition to the two or three pairs of bellows needed for the forge fires." "Each forge had at least two reheating hearths, the 'chafery' and 'finery,' but in some cases there were two fineries, *e.g.*, Staveley, Colnbridge and Kirkstall, and at Wortley there were three fineries, a chafery, a smithy and a bloomery, each with their own bellows and bellows wheels."



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The Week's News in Brief

Trade Talk

IT IS ANNOUNCED that official trade negotiations between this country and Germany may take place early in the New Year.

THE ANNUAL WHIST DRIVE, dinner and dance organised by the Lancashire Branch of the Institute of British Foundrymen will be held at the Grand Hotel, Manchester, from 4 to 11.45 p.m. on February 4.

BURNTISLAND SHIPBUILDING COMPANY, LIMITED, have secured an order to build a motor cargo ship for the British Channel Islands Shipping Company, Limited. The propelling machinery, consisting of an Atlas Polar Diesel engine of 800 b.h.p., will be installed by the Burntisland Company.

THE FOLLOWING FIRMS have been granted licences to manufacture Meehanite metal:—Perry Engineering Company, Australia; Kalgoorlie Foundry Company, Australia; Goninan Company, Australia; Fleming Foundry Company, Springfield, Massachusetts, U.S.A.; Valley Iron Works, St. Paul, Minn., U.S.A.; Barnett Foundry & Machine Company, Newark, N.J., U.S.A.; Herbert Morris, Limited, Loughborough, and Douglas Fraser & Sons, Limited, Arbroath, Scotland.

SIR GEORGE GILLETT, Commissioner for the Special Areas in England and Wales, in his second annual report, states that the commitments embarked on up to September 30 last year were estimated to be £16,770,000, and the actual payments by way of grant or loan amounted to over £8,500,000. In his report for the previous year Sir George Gillett stated that the next 12 months would probably be chiefly concerned with pushing forward work already started. The forecast has proved correct. Experience has proved that attractive trading estates, such as those at Team Valley and Treforest, can secure very considerable support. The progress made is very satisfactory and, given time, there is every reason to expect that the estates will provide a large amount of work for those in the neighbourhood. The Commissioner expresses the hope that, even in advance of the report of the Royal Commission on the Distribution of the Industrial Population, something may be done by voluntary means to correct the tendency for new industries to establish themselves in the London area. But even if some help to the Special Areas is immediately forthcoming as a result of restrictions on the growth of London, he considers it would be a mistake to reduce the powers at present available for encouraging new industrial activity in the Special Areas.

Contracts Open

Cupar, Fife, January 26.—Providing and laying of 12 miles of 18-in. dia. cast-iron and steel water main, for the Fife County Council. Mr. H. F. Hodge, county engineer, 34, Viewfield Terrace, Dunfermline. (Fee £2 2s., returnable.)

Killough, January 13.—Supply and erection of electric motors and pumps; purification plant, for the Downpatrick Rural District Council. Mr. R. J. Carr, clerk, R.D.C. Offices, Downpatrick. (Fee £2 2s., returnable.)

London, S.W., January 13.—Pig-iron (West Coast hematite), for the Bombay, Baroda & Central India Railway Company. The White Mansion, 91, Petty France, Westminster, S.W.1. (Fee £1, returnable.)

Salisbury, February 7.—Iron castings during the year commencing April 1, 1939, for the City Council. Mr. S. R. Little, city engineer, The Council House, Bourne Hill, Salisbury.

Company Reports

Qualcast, Limited.—Interim dividend of 10 per cent.

Ewart & Son, Limited.—The preference dividend falling due on December 31 will not be paid for the time being.

Barton & Sons, Limited.—Further interim dividend of 2 per cent. on the ordinary shares in respect of the period ending December 31.

Indian Iron & Steel Company, Limited.—Directors state that it is not their intention to consider the question of an interim dividend payment before the end of March or the beginning of April.

New Year's Honours

The list of New Year's Honours contains the names of a number of people prominent in the foundry and related industries.

SIR PETER RYLANDS, a Past-President of the Iron and Steel Institute, has been created a Baronet.

MR. E. J. GEORGE, a director and general manager of the Consett Iron Company, Limited, and a Past-President of the British Iron and Steel Federation, has been created a Knight.

SIR FRANK SMITH has been promoted to a G.B.E. He is Secretary of the Department of Scientific and Industrial Research, and until recently was the Secretary of the Royal Society.

DR. J. D. POLLOCK, at one time Chairman of the British Oxygen Company, has been created a Baronet.

MR. E. R. CANNING, chairman of W. Canning & Company, Limited, of Birmingham, has been created a Knight.

DR. S. J. PIGOTT, the managing director of John Brown & Company, of Clydebank, has been created a Knight.

Personal

MR. M. J. RAILING, vice-chairman and joint managing director of the General Electric Company, Limited, has been presented by employees of the company at home and overseas with a portrait of himself, painted by Harold Knight, R.A., to mark the occasion of his 70th birthday last July.

MR. GEORGE B. BROOK, F.I.C., chief chemist of the British Aluminium Company, Limited, at Kinlochleven, for 18 years, retired under the 65-years' age-limit recently. He was recently elected a Fellow of the Royal Society of Edinburgh. A native of Sheffield, Mr. Brook was at one time a lecturer at Sheffield University. In an interview Mr. Brook said that he left Kinlochleven with a great personal regret, particularly his many friends of long standing. When he came to Kinlochleven there were 15 in the laboratory; now there were 55.

Wills

HELM, R. W., a director of Allied Ironfounders, Limited	£24,477
FELLOWS, D. V. L., chairman of the Patent Die Castings Company, Limited	£26,196
BAGGS, B. W., late managing director of Crowden & Keeves, Limited, hardware manufacturers	£22,127

Obituary

MR. CHARLES HALL BETTS, founder of Charles H. Betts & Company, Limited, bronze and aluminium powder merchants, Birmingham, has died, aged 75.

MR. THOMAS BEGG, who was employed for 50 years at Port Downie Iron Works, Falkirk, as an ironmoulder, retiring two years ago, has died in Falkirk.

MR. ANDREW AULD, of Stirling, one of the founders and first chairman of the Broomside Foundry Company (1922), Limited, Bonnybridge, Scotland, has died, aged 68.

Applications for Trade Marks

The following list of applications to register trade marks has been taken from the "Trade Marks Journal":—

"BRYTALLIUM."—Brytallium Metal Company, Limited, 26, Brazennose Street, Manchester, 2.

"TRAFFOCELE."—Metals and alloys. Metropolitan-Vickers Electrical Company, Limited, Number One, Kingsway, London, W.C.2.

"ARGALIUM."—Aluminium alloys. Briske & Prohl, c/o S. Sokal, 1, Great James Street, Bedford Row, London, W.C.1.

Patent Specifications Accepted

The following list of Patent Specifications accepted has been taken from the "Official Journal (Patents)." Printed copies of the full Specifications are obtainable from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each. The numbers given are those under which the Specifications will be printed and abridged, and all subsequent proceedings will be taken.

492,930. BRITISH THOMSON-HOUSTON COMPANY, LIMITED. Electric welding systems.

492,932. NAAMLOOZE VENNOOTSCHAP PHILIPS' GLOEILAMPENFABRIEKEN. Coated welding rods.

493,013. FONDERIE BRUNEAU FRERES. Apparatus for casting metallic products.

493,025. ACIERIES DU CENTRE, and MAGNEE, J. Device for automatically locking cores in moulds.

493,028. ROCHLING'SCHE EISEN-UND STAHLWERKE GES. Bright annealing furnace.

493,058. RODMAN CHEMICAL COMPANY. Carburising of iron, steel and alloy steels.

493,184. OFAG OFENBAU AKT.-GES., and SCHOECK, W. Continuous annealing or like heat-treatment furnaces.

493,225. JONES, L., and METROPOLITAN-VICKERS ELECTRICAL COMPANY, LIMITED. Arc-welding apparatus.

New Company

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Temple Metal Company, Limited, 106, Edmund Street, Birmingham.—Capital, £2,500. Non-ferrous metal founders, etc.

Forthcoming Events

JANUARY 9.

Society of Chemical Industry:—"Creep in Non-Ferrous Metals," Paper by Dr. J. McKeown, at Burlington House, London, W.1.

JANUARY 10.

Institute of Welding (Tyneside Branch):—"Castings and Weldings," Paper by G. Pearson, at Armstrong College, Newcastle-upon-Tyne, at 7.30 p.m.

JANUARY 11.

Institute of Welding (Scottish Branch):—Discussion on cast-iron welding, at 207, Bath Street, Glasgow, at 7.30 p.m.

JANUARY 12.

Institution of Mechanical Engineers (Yorkshire Branch):—"Cast Iron," Paper by J. E. Hurst, at Hotel Metropole, Leeds, at 7.30 p.m.

JANUARY 13.

Manchester Association of Engineers:—"Trends in Heavy Machine-Tool Design and Operation," Paper by J. H. Rivers, at Engineers' Club, Manchester, at 7.15 p.m.

Institute of British Foundrymen

JANUARY 7.

Lancashire Branch:—"Some Interesting Examples in Loam Moulding," Paper by R. D. Lawrie, at Engineers' Club, Manchester, at 4 p.m.

Wales and Monmouth Branch:—"Why Not Green Sand?" Paper by F. Whitehouse, at University College, Cardiff, at 6 p.m.

JANUARY 10.

Burnley Section:—Paper on "Manufacture and Application of Grinding Wheels," at Municipal College, Burnley, at 7.30 p.m.

Newcastle-upon-Tyne Branch:—Joint meeting with Institute of Metals (North-East Coast Section) at King's College, Newcastle-upon-Tyne, at 7.30 p.m.

JANUARY 13.

Middlesbrough Branch:—Debate with kindred Tees-side society, at Cleveland Scientific and Technical Institution, Middlesbrough, at 7.45 p.m.

JANUARY 14.

Scottish Branch:—"Relation of Moisture to Principal Properties of Moulding Sands," Paper by J. Dearden, and "Impressions of Modern Foundry Practice," Paper by H. Lowe, at Royal Technical College, Glasgow, at 4 p.m.

West Riding of Yorkshire:—Annual dinner and dance at Great Northern Victoria Hotel, Bradford.

The Institute of Vitreous Enamellers

JANUARY 10.

Extraordinary General Meeting:—To consider Article 28 of the Articles of Association, at Chamber of Commerce, New Street, Birmingham, at 3 p.m.

JANUARY 12.

Southern Section:—"Electric Furnaces for Vitreous Enamelling," Paper by A. G. Robiette, at Charing Cross Hotel, London, at 8 p.m.

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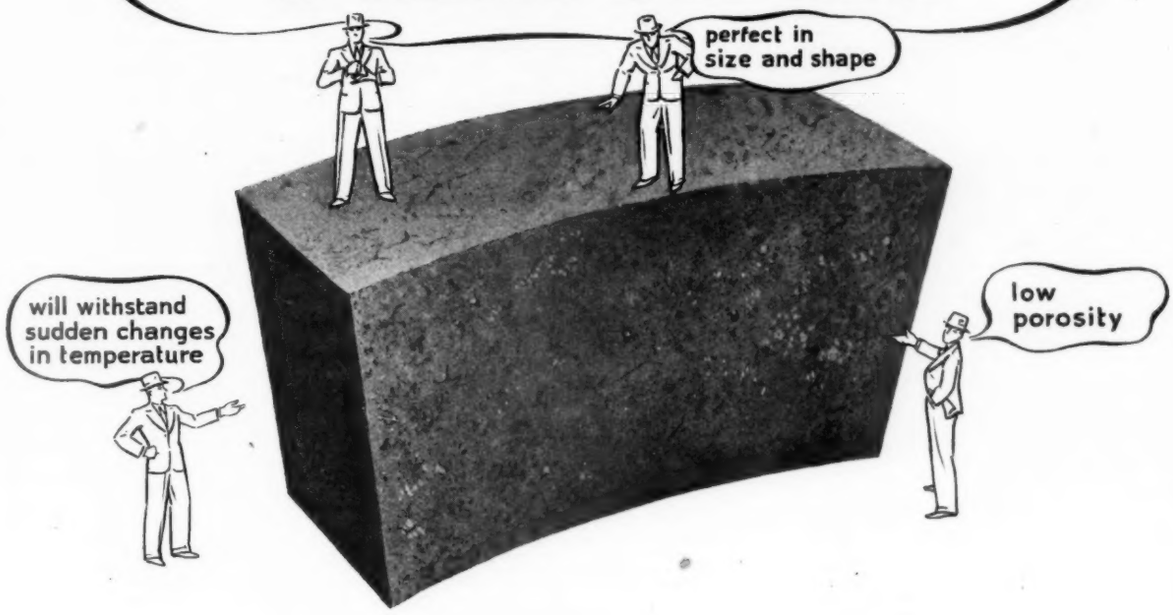

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Raw Material Markets

Now that the new price schedules for iron and steel products are in operation makers hope within a short time to be able to gauge the extent of consumers' requirements. Already some orders have come to hand, but New Year holidays have not allowed business to settle down as yet. The outlook has been considerably brightened by the announcement by Sir John Anderson that an early start is to be made in providing air-raid shelters for the entire civil population. Several sections of the steel industry will benefit, but more especially the sheet makers.

Pig-Iron

MIDDLESBROUGH.—The last few days of December were extremely quiet. Within a short time, however, it is expected that there will be a good call for deliveries, while many users are likely to enter into new contracts. For delivery in the Middlesbrough and Falkirk areas, No. 3 Cleveland foundry iron is now quoted at 99s., No. 1 foundry 102s., and No. 4 foundry and No. 4 forge 98s. Deliveries to Clydeside are invoiced at 3s. above the foregoing prices.

Although it is expected that there will be some new ordering of hematite, it is unlikely that there will be any need for producers to expand their current low outputs, as the majority of users have still large tonnages to take up under old contracts. The revised quotations for East Coast mixed numbers are 120s. on the North-East Coast, 125s. 6d. in Sheffield, and 131s. in the Midlands, all less 5s. per ton rebate.

LANCASHIRE.—With many users' stocks of foundry iron at a low ebb, it is hoped that there will be some good orders available in this area as soon as the consumers have concluded their annual stocktaking operations. For the most part, however, trade will be confined to the despatch of deliveries under contracts entered into some time ago. Under the revised schedule it is now possible to purchase as far ahead as the end of June next. For delivery in the Lancashire price zone, offers of Staffordshire and Derbyshire No. 3 foundry irons are at £5 4s., with Northamptonshire at £5 2s. 6d. Derbyshire forge iron is now quoted at £5 1s. to £5 3s., according to the class of consumer. As yet, the lower prices of hematite appear to have had little effect on the market, but an expansion in trade is looked for after stocks have been checked at the consuming plants.

MIDLANDS.—The foundry iron market in this area opens the New Year with a fairly confident tone, despite the fact that there has been little buying of high-phosphorus iron for some months. Of late, only small tonnages have been changing hands, but the lower prices now ruling are likely to have the effect of considerably expanding the demand. An unsatisfactory feature of the trade is the dull state of the light-castings section, and it is not anticipated that there will be much improvement here until the spring, as the building trade remains very quiet and is one of the largest consumers of light castings. Other sections, however, have already indicated their disposition to take up tonnages at the new prices, which are: £5 1s. for Derbyshire No. 3, and £4 18s. 6d. for Northamptonshire No. 3, delivered Birmingham and Black Country stations and subject to 5s. per ton rebate. Low-phosphorus iron at from £5 5s. to £6, delivered works in this district, is in quite good demand, but hematite is still only being called for in moderate tonnages, as most consumers are well stocked. In any case, there is not likely to be much new business for some time, as existing contracts will be sufficient to meet users' needs.

SCOTLAND.—The New Year has opened very quietly in this area, as most of the producers' and consumers' works are idle owing to the usual holidays. In many cases the opportunity is being taken to repair plant where necessary. However, within a short time works will again be in operation and it is expected that there will be a fairly strong call for deliveries of foundry iron at the lower quotations, which are 105s. 6d. for Scottish No. 3 foundry iron, f.o.t. furnaces, with 2s. 6d. extra for No. 1. The light-castings section of the trade is taking a more hopeful view of the New Year, but not before the spring will the activity in this section return to more satisfactory conditions than have obtained over the past few months. Prices of steel-making irons are as follow: Hematite mixed numbers, 120s. 6d.; basic, 100s., both less 5s. rebate, delivered steelworks here.

Coke

Many consumers of foundry coke are covered for supplies up to the end of March, while very few have any pressing needs to cover, so that there is not a great deal of activity in the market at the present time. The price of Durham foundry coke is reaffirmed at 34s. 6d. f.o.r. ovens for the first half of the year. Blast-furnace coke has been reduced to 24s. 2d. per ton at Durham ovens, which is equivalent to 28s. delivered Middlesbrough furnaces.

Steel

A brighter New Year has been guaranteed to the steel market by Sir John Anderson's announcement to the effect that the Government intends to provide air-raid shelters for the entire civil population of the country. Steel sheets will be mostly required for this purpose, and as this section has been especially quiet for some time the new outlet for supplies will be all the more appreciated. On the whole, it is thought that the steel market may view the New Year in a rather more favourable light, but the continued lack of export business will remain a source of anxiety to producers.

Scrap

The holidays have accentuated the quiet tone of the iron and steel scrap market in all districts. Deliveries have been considerably reduced. Most steelmakers are well covered by existing stocks of scrap and not much increase of business is likely to result for a time from the lower quotations that have been brought into operation. In any case, steel production is at a very unsatisfactory level.

Metals

Copper.—There has been little activity in this market during the past week or so and business is likely to remain quiet until after stocktaking operations have been concluded. The London Metal Exchange was closed on Monday, January 2, in celebration of the New Year. Better reports from Wall Street have recently helped to impart a firmer tone to the market, while the fact that restriction of production is now again in operation has also tended to strengthen prices. Looking ahead, the demand for this metal for armament purposes is almost certain to be well maintained, if not intensified, during the coming year, while the industrial outlook in the United States appears to be improving. The greatest uncertainty, of course, is the international outlook, which cannot be said to be at all reassuring at the present time.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £44 8s. 9d. to £44 10s.; Friday, £44 10s. to £44 12s. 6d.; Tuesday, £44 11s. 3d. to £44 12s. 6d.; Wednesday, £44 6s. 3d. to £44 7s. 6d.

Three Months.—Thursday, £44 15s. to £44 16s. 3d.; Friday, £44 15s. to £44 17s. 6d.; Tuesday, £44 16s. 3d. to £44 17s. 6d.; Wednesday, £44 11s. 3d. to £44 12s. 6d.

Tin.—The tin market closed the year on a strong note. On Friday the forward quotation touched a new high level for the year, while cash was also considerably higher than the previous quotation. This was entirely due to heavy buying reports from the United States. In this country Christmas and New Year holidays have disturbed the normal trend of business and consumers are now showing very little interest in additional buying.

According to the statistics compiled by Mr. W. H. Gartsen (Henry Rogers, Sons & Company), the total visible supply of tin at the end of December was 29,494 tons, or 38 tons less than the total on November 30. These figures include the carry-over in Straits Settlements and at the Arnhem (Holland) smelter.

Official quotations were as follow :—

Cash.—Thursday, £216 10s. to £216 15s.; Friday, £217 to £217 10s.; Tuesday, £217 to £217 5s.; Wednesday, £217 to £217 5s.

Three Months.—Thursday, £217 15s. to £218; Friday, £218 to £218 2s. 6d.; Tuesday, £218 to £218 5s.; Wednesday, £218 to £218 5s.

Spelter.—A rather colourless tone has recently prevailed in this market and the immediate outlook is not particularly encouraging. The American Bureau of Metal Statistics announces that the daily rate of world smelter output of zinc increased in October to 4,601 short tons, as compared with 4,398 tons in the previous month.

Daily market prices :—

Ordinary.—Thursday, £13 16s. 3d.; Friday, £14; Tuesday, £13 13s. 9d.; Wednesday, £13 15s.

Lead.—There has not been much business transacted during the past week, but the tone of the market is steady and the outlook not unfavourable. In the United States, there has been a good deal of buying of late and the domestic market has been active. The world output of lead in October, according to the American Bureau of Metal Statistics, totalled 155,745 short tons, as compared with 149,189 tons in September.

Soft Foreign (Prompt).—Thursday, £15 3s. 9d.; Friday, £15 8s. 9d.; Tuesday, £14 17s. 6d.; Wednesday, £14 16s. 3d.

Scrap.—Business has been negligible during the past week; the outlook for 1939 does not seem to offer much hope of any early improvement on the rather difficult trading conditions which prevailed over the best part of last year.

Consistency of Enamel Frits

(*Concluded from page* 16.)

of 12 at 839 deg. C., have approximately the same apparent viscosity when the temperature of frit 6 is 133 deg. C. higher than that of frit 25.

In practice, the differences in the temperatures at which different enamels are fired are not sufficient to bring them all to the same apparent viscosity. Thus, it is common for the surface of an acid-resisting enamelled article to be more wavy than that of an article with an "ordinary" enamel, a condition which indicates more resistance to flow in the case of the former. Nevertheless, from a knowledge of the range of firing temperatures ordinarily used for different types of enamel, considered in conjunction with Fig. 4, it may be estimated that 4,000 poises (3.6 on the ordinate) represents the order of magnitude of the average viscosity (or apparent viscosity) attained by enamels during firing.

The lowest apparent viscosity measured (see Fig. 9) was 155 poises for frit 72 at 930 deg. C. and the highest (see Fig. 5) was 61,000 poises for frit 6 at 796 deg. C. It may be estimated by extrapolation that at 750 deg. C., at or near which temperature most of the frits were tested, the apparent viscosity of frit 6 would exceed 200,000 poises.

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